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Stock Status and Genetics of Coho Salmon from the Interior Fraser River

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ABSTRACT

We evaluated the impacts of continued restrictions in salmon harvest on the status of coho salmon of the interior Fraser River, including the Thompson drainage in 1999. Total exploitation rate on the aggregate in 1999 was estimated to be ~9% (~3% Canadian, ~6% US), which is similar to 1998, and much lower than in previous years. Various indices of escapement suggest the total spawning population in 1999 was about the same as in 1998, but higher than the 1996 parental escapement. Total abundance in 1999 was about 10% of that observed 10-15 yrs ago, and spawning populations in many streams are small or non-existent. We conclude that the status of the aggregate is largely unchanged from 1998, and remains poor. It is premature to draw any conclusion about whether the better survival of the 1996 brood (1999 return) represents a trend towards improved survival in the future. We have no basis to alter the conclusion reached in this year's forecast document (Holtby et al. 2000) that it is unlikely that stock size will increase in 2000.

The potential for traditional ecological knowledge to assist in stock assessment was discussed, as were recent enhancement activities in the interior region. Analysis of genetic information on interior Fraser coho supported the idea that non-Thompson coho can be grouped with Thompson coho as a single management or conservation unit that is distinct from lower Fraser.

The major recommendations from this paper are:

1. Target and limit reference points for Interior Fraser River coho are needed to provide management advice relative to current abundance levels and forecast trajectories.

2. Policies on the role and evaluation of strategic enhancement to restore declining populations such as the Thompson need to be formulated.

3. More extensive baseline coverage of interior Fraser coho for genetic sampling (e.g. Nahatlatch) are needed to aid in the delineation of populations, and provide more precise estimates of the distribution and numbers of interior Fraser coho in catches.

RÉSUMÉ

Les auteurs ont évalué les conséquences des restrictions permanentes de la récolte de saumons sur l'état de la population de saumons coho dans le cours supérieur du fleuve Fraser, y compris le drainage de Thompson River en 1999. On estime qu'en 1999, le taux d'exploitation total de l'ensemble de la ressource est d'environ 9 % (~ 3 % au Canada, ~ 6 % aux États-Unis), une valeur semblable à celle de 1998 et très inférieure à celles des années antérieures. Divers indices d'échappement suggèrent qu'en 1999, la population frayante totale est environ la même qu'en 1998, mais supérieure à l'échappée parentale de 1996. L'abondance totale, en 1999, équivaut à environ 10 % de celle d'il y a 10 à 15 ans et dans de nombreux cours d'eau, la population frayante est faible ou inexistante. Nous en concluons que l'état de l'ensemble de la ressource est largement inchangé par rapport à 1998 et qu'il demeure médiocre. Il est trop tôt pour tirer une conclusion du meilleur taux de survie de la génération de 1996 (remonte de 1999) et pour établir s'il représente une tendance d'amélioration future du taux de survie. Nous ne possédons aucune donnée permettant de modifier la conclusion du document de prévisions de cette année (Holtby et coll., 2000) selon laquelle il est peu probable que les stocks augmenteront en 2000.

Nous discutons de la possibilité d'employer les connaissances traditionnelles en environnement pour aider à évaluer les stocks, ainsi que des récentes activités de mise en valeur dans la région de l'intérieur. Les résultats de l'analyse de l'information génétique des saumons coho du cours supérieur du Fraser renforcent l'idée selon laquelle on peut regrouper les cohos de la Thompson et ceux qui se trouvent dans d'autres cours d'eau en une seule fraction de gestion ou de conservation qui soit distincte de celle du cours inférieur du Fraser.

Voici les principales recommandations du présent article :

4. Il est nécessaire d'établir des points de référence cibles et limites pour les cohos du cours supérieur de Fraser River afin de fournir des conseils en matière de gestion des niveaux actuels d'abondance et des prévisions de trajectoires.

5. Il est nécessaire d'élaborer des politiques ayant trait au rôle et à l'évaluation de la mise en valeur stratégique qui vise à reconstituer les populations décroissantes comme celle de la Thompson.

6. Il est nécessaire d'effectuer un plus vaste ensemble d'observations des lignes de base des cohos du cours supérieur du Fraser, en matière d'échantillonnage génétique (p. ex., Nahatlatch), afin de faciliter la délimitation des populations et d'obtenir des estimations plus précises du nombre de cohos du cours supérieur du Fraser dans les prises et de leur distribution.

I. Introduction

The Interior Fraser River Management or Conservation Unit (Wood 1998) is defined as the Fraser River watershed upstream of Hells Gate and includes the Thompson River, the largest watershed within the Fraser River system (Fig. 1). Coho salmon originate in four sub-regions: (1) South Thompson - mainstem South Thompson River and tributaries upstream from the confluence of the North Thompson River; (2) North Thompson - mainstem North Thompson River and tributaries of it; (3) Lower Thompson - mainstem Thompson and tributaries downstream from the confluence of the North Thompson including the Nicola watershed; and (4) Non-Thompson – Fraser River and tributaries upstream of the Fraser Canyon excluding the Thompson. Coho are found well upstream of the northern boundary shown on Fig. 1 although generally in limited numbers; for example they have been documented in the Nechako River drainage, west of Prince George.

This is the third annual assessment of interior Fraser coho. It shares with last year's document (Irvine et al. 1999b) the objectives of providing an overview of fishery regulatory changes implemented to conserve Thompson coho and critically examining fishery and spawner escapement data to determine the effectiveness of these changes. In addition, in this year's assessment we introduce the topic of traditional ecological knowledge and explore ways of incorporating it into future stock assessments, we examine the genetics of interior Fraser coho, and we consider the role of freshwater habitat in the decline of Thompson coho. In addition, we update information on the status of biological enhancement and trends in productivity and spawner distributions.

II. Traditional Ecological Knowledge

A consideration of Traditional Ecological Knowledge (TEK) is requested for stock assessments submitted to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). TEK is routinely incorporated into fish and wildlife management decision-making processes throughout Canada's north (Robinson et al. 1994, Legat 1991), and is an integral part of Traditional Use Studies (TUS) prepared in support of forest and land management and water use planning processes within the BC. In the Pacific salmon arena, we are just beginning to explore the subject, but the growing influence of Aboriginal people in salmon management, and the likelihood that COSEWIC will soon review the status of Thompson coho, lead us to believe that we should include a discussion of TEK in this report.

The purpose of this section of the report is to briefly discuss TEK and the role it can play in stock assessments, and to provide advice on how TEK could be gathered for future assessments.

We restrict our definition of TEK to be that knowledge originating from First Nations peoples although other definitions are possible. We view TEK as an untapped and potentially valuable stock assessment resource. For thousands of years, Aboriginal people lived in the Interior Fraser catching salmon and observing nature. Communities such as those in the Interior Fraser with a long history of resource use can be expected to have acquired a deep but qualitative knowledge about the resource that they depended upon (Kurien 1998). It is prudent to consider whether these observations are consistent with and supportive of, contemporary scientific stock assessment views and advice.

"The lack of common understanding about the meaning of traditional knowledge is frustrating for those who advocate or attempt in practical ways to recognize and use traditional knowledge. For some, traditional knowledge is simply information which aboriginal people have about the land and animals with which they have a special relationship. But for aboriginal people, traditional knowledge is much more. One elder calls it a "a common understanding of what life is about."" (Legat 1991).

Many aboriginal people have fished in the same places all their lives, and can trace their family's use of a particular site back through uncounted generations. Observations spanning many lifetimes and stories stretching back for thousands of years can provide insights into the way things used to be that simply couldn't be obtained from any other source. TEK also includes rules and customs that served to allocate and conserve the fisheries resource. For example, Stewart (1977) reported that in some fishing communities salmon could not be carried up the bank in a basket, but had to be carried up one in each hand. Kew and Griggs (1991) commented on the practice of immediately opening fish weirs following a night of fishing.

Obtaining TEK

In order to access traditional ecological knowledge within a particular Community, one must be prepared to establish a relationship with both the Band administration and the individuals you want to talk to. If one doesn't have the time, he/she will have to hire and train someone from the community. Questions and interview procedures require considerable care, as does the need to provide specific training to community members that will conduct the interviews (Johnson 1992). As Robinson et al. (1994) emphasized, "the fundamental issue is one of receiving shared information rather than taking information".

Many BC Native communities are involved in resource management and planning processes, or are preparing, or have already prepared TUS. While TUS often contain useful information about fish and fisheries, most focus on land use (forestry) issues. Many Native communities have resource people to assist in developing, conducting, and interpreting these studies and have a relationship with the people one needs to interview. Investigators should not enter native communities without first approaching the Band administration. [1]

Interior Fraser coho return to spawn primarily within the traditional territories of the Secwepemc people (North and South Thompson and Clearwater rivers) and of the Nlaka'pmux, Sce'exmx and Okanagan people of the upper Fraser canyon and Nicola valley. Some coho spawning also takes place within the traditional territories of the St'at'imc, (Lillooet/Bridge River areas) and Tsilhqot'in (Chilcotin river system). The Shuswap Nation Fisheries Commission (SNFC) and the Nicola Valley Stewardship and Fisheries Authority (NWFSA) have knowledge of traditional fisheries, however several Secwepemc bands are not affiliated with the SNFC (including the Nesconlith and Adams Lake Bands). Both the SNFC and NWSFA are involved in the preparation of TUSs, and could assist in developing and implementing fisheries specific studies.

How to use TEK

"Appropriate use will depend on the situation, activity and the requirements of various institutions and most importantly, the wishes of the aboriginal people affected" (Legat 1991).

Most salmon stock assessment professionals are interested in understanding long term changes in distribution, abundance, and harvest of the stocks in question. A variety of issues arise in the collection and use of TEK in support of stock assessment work. Assuming information was collected specifically for particular projects there should be few difficulties. Investigators should ensure that they have permission to use the information they collect in the way they propose to use it. Much of this information may be viewed as belonging to the individuals and communities that provided it.

[1] Contact numbers for BC First Nations and Tribal councils and individual bands are available at: http://www.aaf.gov.bc.ca/aaf/nations/nations.htm.

Perhaps a more pressing issue relates to the need to integrate TEK and Western science. Johnson (1992) covers this issue in some detail. " Why are TEK and Western science so difficult to integrate? First there is the urgent problem of the disappearance of TEK and the lack of resources to document it before it is lost. Second, there are the practical problems of trying to reconcile two very different world views and trying to translate ideas and concepts from one culture into another. Third, cultural barriers and misunderstandings prevent both Western scientists and aboriginal peoples from acknowledging the value of each others knowledge systems." Incorporating TEK into stock assessments will be a major challenge.

Recommendations concerning TEK

Traditional Ecological Knowledge is not a simple footnote that provides some measure of additional information in support of scientific stock assessment. TEK is a way of life and is a study in its own right. Studying and using the TEK of First Nations will require a significant commitment. If we intend to incorporate TEK as a routine part of Stock Assessment work, staff will require specific training and resources will need to be allocated to these projects. Perhaps the most efficient way to proceed in the Fraser is through the development of a protocol with Fraser First Nations laying out the type of information sought, the way the information will be used, and the roles of DFO and Fraser First Nations in collecting and interpreting the information.

Before it can be used in a scientific stock assessment, TEK will need to be subjected to the same sorts of quality control measures as other scientific information is. Data sources will have to be documented, information rated as to its reliability, and alternative methods used to verify information when possible.

III. Genetic Diversity of Fraser River Coho Salmon

Methods

Approximately 2000 adult coho salmon sampled from the interior Fraser River region and 1800 coho salmon sampled from the lower Fraser River were surveyed for genetic variation at seven microsatellite loci and one MHC class I locus (Miller and Withler 1997). Locations and dates of sample collections for the interior coho salmon are shown in Table 1. Analysis of the allelic and genotypic frequency data was carried out using the Genetic Data Analysis program of Lewis and Zaykin (2000) and GENEPOP version 3.1d (Raymond and Rousset 1985). Fst and Nei's (1978) genetic distance values were computed among tributaries, among basins and between the interior and lower Fraser River regions. Fst (or the coancestry coefficient) is the correlation of genes of different individuals in the same population and can range from 0 to 1. Positive estimates of Fst values for a group of samples indicate that the individuals of each sample are more closely related to each other (i.e. have a more recent common ancestor) than they are to individuals of the other samples. Nei's (1978) genetic distance is a standard distance metric based on differences in allele frequencies between samples. Hierarchical analyses of the variation among years, among tributaries within basins, and among basins within regions were conducted. Fst values were clustered with the neighbour-joining algorithm to illustrate the genetic relationships among sample sites throughout the Fraser drainage and among years, tributaries and basins in the upper Fraser drainage.

Genetic differentiation of lower and interior Fraser River coho salmon

Strong genetic differentiation between the coho salmon of the lower and interior Fraser River drainages is apparent at both neutral (microsatellite) loci and a potentially adaptive (MHC) locus (Fig. 2, Table 2). The differentiation between lower Fraser and Thompson River coho salmon has been observed in prior studies based on allozyme loci (Wehrhahn and Powell 1987) and a limited number of microsatellite loci

(Small et al. 1998a, 1998b), but few samples of interior Fraser coho from upstream of the Fraser-Thompson confluence have been studied, and none downstream. Genetic data have consistently supported the suggestion of independent phylogeographic origins for salmonids inhabiting the lower and interior portions of the Fraser River drainage (Wood et al. 1994, Small et al. 1998a, Teel et al. 2000). Lower Fraser coho salmon are genetically similar to southern coastal and Vancouver Island populations in British Columbia and Puget Sound populations in Washington, but those of the Thompson River are the most distinctive coho salmon examined to date, with no strong genetic affinity to other coho salmon populations surveyed from Washington to southeast Alaska (Small et al. 1998b, Shaklee et al. 1999, unpublished data). The samples of non-Thompson interior coho salmon analyzed in this study (Bridge River and McKinley Creek) were distinctive from both lower Fraser and Thompson River coho salmon, but showed greater genetic affinity to the Thompson River samples at both microsatellite and MHC loci (Table 2). This indicates a common origin for all coho populations sampled upstream of the Fraser River canyon.

Genetic variation at the microsatellite loci and the MHC locus in Fraser River coho salmon was structured similarly on a geographic basis. The same dendrogram of population structure resulted from analysis of the seven-microsatellite loci alone, and from the microsatellite and MHC loci combined (Fig. 2). The strong differentiation between coho salmon sampled from lower Fraser and interior sites was apparent in pairwise comparisons among sites for both types of loci (Table 2) and in the hierarchical analysis of gene diversity (Table 3). In comparisons among populations within the lower and interior watershed regions, Fst values tended to be the same or somewhat higher for the MHC locus than for the microsatellite loci (Table 2) and the variation attributed to tributaries and years within basins was the same for both types of loci (Table 3). For pairwise comparisons between the interior and lower Fraser regions, Fst values for the MHC locus were higher than those for the microsatellite loci and the upper/lower split of the drainage accounted for four times more of the variance in the MHC allele frequencies than of microsatellite allele frequencies (Table 3).

Private alleles (those found exclusively in one region) were observed for lower and/or interior Fraser coho salmon at all seven microsatellite loci, but their frequencies were low (accounting for less than 6% of the alleles present at any locus). Approximately four times as many private microsatellite alleles were present in the lower Fraser (53) as in the interior (14) coho salmon sampled. In contrast, six private alleles accounted for 21% of the MHC alleles scored in lower Fraser coho salmon. No private MHC alleles were observed in interior coho salmon, the distinctiveness of these fish at the MHC locus due to the absence of MHC alleles common to coho salmon elsewhere and unusually high frequencies of three alleles that tend to be present at lower frequencies elsewhere. The greater genetic differentiation of lower and upper Fraser River coho salmon at the MHC locus (Fst = 0.12) than the microsatellite loci (Fst = 0.034) may reflect the influence of selection on the MHC locus. If so, the amount of gene flow between the lower and interior Fraser regions has been insufficient to counteract the selective advantage of the restricted MHC class I allelic repertoire in interior coho salmon. Evidence for adaptive differentiation in morphology and swimming performance between lower and interior Fraser River coho salmon has also been found (Taylor and McPhail 1985a, 1985b).

Genetic structure of interior Fraser River coho salmon

Temporal variation

Allele frequencies for at least one microsatellite locus varied significantly among samples collected in different years for all but one of the 11 interior Fraser tributaries sampled over time. This level of temporal variation is higher than that commonly observed for Pacific salmon samples collected over such a short time frame and may be influenced by the relatively small annual sample sizes (Table 1) and/or accelerated genetic drift resulting from low abundances of interior coho salmon in recent years. Nevertheless, temporal variation accounted for only 0.6% of the observed variation in microsatellite allele frequencies in the interior Fraser region (Table 4). MHC allele frequencies varied significantly over time only for the multiple samples collected from Dunn and Louis creeks, but 0.6% of the variation at the MHC locus was also due to temporal variation within tributaries (Table 4).

Geographic structure
In the hierarchical analysis of genetic variation within the Thompson drainage (as defined in Table 1 except that the Bridge River and McKinley Creek sites were excluded), over 96% of the observed variation in microsatellite frequencies, and 89% of variation at the MHC locus, occurred within samples (Table 4). Differentiation among tributaries within basins was equivalent to or only slightly greater than the temporal variation within tributaries, accounting for 0.8 and 0.9% of the microsatellite and MHC variation, respectively (Table 4). In contrast, individual basins accounted for 2.3 and 9.4% of the observed variation in microsatellite and MHC allele frequencies, respectively. Thus variation among basins was three times greater than variation among tributaries within basin at microsatellite loci, and ten times greater at the MHC locus.

The relatively strong influence of basin and weaker influence of tributary within basin is apparent in the dendrogram of interior Fraser samples, in which multiple samples from the same tributary do not always group together, but always cluster within the correct basin (Fig. 3). In the hierarchical analysis, samples from the Salmon and Eagle rivers were treated as belonging to the same basin (to maintain a balanced design) (Table 1), although in fact the Eagle and Salmon rivers are independent drainages flowing into Shuswap Lake. The differentiation of coho salmon from these two basins (Fig.3) may have contributed substantially to the estimates of the variation among tributaries within basin. For that reason, a hierarchical analysis of temporal variation within tributaries and among tributaries within basins for the two best-sampled Thompson basins (the North Thompson River and the Nicola River) was carried out (Table 5). For these two basins, the temporal variation was as great as geographic variation for both the microsatellite and MHC loci (Table 5). The Bridge River and McKinley Creek samples of the upper Fraser drainage were not included in the hierarchical analyses because the McKinley Creek site has been sampled only once. However, Fst and genetic distance values indicate that these two sites from the upper Fraser are as differentiated from Thompson basins as the Thompson basins are from each other (Fig. 3, Table 2).

The 3.2% of genic diversity at microsatellite loci attributed to geographic structure in interior Fraser coho salmon is similar to the 3.9% reported for coho salmon throughout the Skeena River system (Wood and Holtby 1998). As in the Skeena, genetic differentiation in the interior Fraser region occurs primarily among major basins, although the geographic distances among basins sampled are less in the Fraser than in the Skeena. At the MHC locus, geographic structure accounted for three times more (10%) of the observed genic diversity. The increased differentiation was apparent entirely among basins, rather than among tributaries within basins (Table 5). As for the differentiation between the lower and interior Fraser drainages, the relatively high level of MHC differentiation among interior basins relative to that observed at microsatellite loci indicates that the selective advantage of MHC alleles or genotypes is greater than the genetically-effective migration rate among basins. Only at the level of tributary within basin is the differentiation observed at the microsatellite and MHC markers equivalent, indicating that selection on the MHC locus does not vary on this geographic scale, or that gene flow among tributaries is sufficient to prevent differentiation as the result of varying selective pressures. For both the microsatellite and MHC loci, temporal variation within tributaries was as great as geographic variation among tributaries within two basins. For samples collected from populations at equilibrium values of drift and migration, this would indicate that the coho salmon of each basin constitute single populations with no geographic differentiation. Given the rapid decline in abundance of interior Fraser River coho over the past two decades, populations of the region are almost certainly not at equilibrium values for genetic drift or migration. Thus, it is not possible to conclude that genetic substructure within basins does not exist (especially given the small sample sizes of this study), simply that any differentiation at this geographic scale is much less than that observed among interior basins, and between the lower and interior Fraser regions.

Conclusions
Fraser River interior coho salmon are the most genetically distinctive component of species diversity included in genetic surveys of populations from Oregon to southeast Alaska at both coding (potentially adaptive) and non-coding (neutral) loci. Migration of interior coho salmon among different Thompson River basins and between the Thompson and upper Fraser drainages is sufficiently restricted to allow local adaptation to occur, and allele frequencies at the MHC class I locus surveyed provide evidence of such adaptation. No evidence for temporally stable population structure among tributaries within basins was provided by the microsatellite or MHC data of this study, but further sampling is warranted to confirm this finding.

IV. Enhancement Status Overview

The Canadian Salmonid Enhancement Program (SEP) was initiated in 1977 to rebuild stocks and increase catches through the expanded use of enhancement technology. Enhancement in the Interior Fraser Management Unit began in the early 1980's. There are 13 enhancement projects producing coho as well as habitat restoration ongoing at various sites. Most of the projects are in the Thompson River system, with only minor enhancement occurring in other parts of this management unit.

There are no large production facilities. Descriptions of the facilities and their targets were presented in Irvine et al (1999a). Production peaked during the mid to late 1980's (Fig. 4), when different enhancement strategies were being tested for coho in the Eagle, Salmon, and Coldwater systems. The objectives were to evaluate the different strategies and to assess the impact of enhanced production on natural stocks (Perry 1995, Pitre and Cross 1993). Supplementation was in the form of spring fed fry, fall fry, and yearling smolt releases. Fish were marked by removing the adipose fin and inserting a coded-wire tag (CWT). The success of the enhanced component was measured using survival rates calculated from tag data, while the success of the naturally spawning component was measured by returns of natural spawners.

From an enhancement perspective, the Coldwater program was successful. During 1987-1991, survival rates for fry and smolt releases were reasonably consistent and total escapements generally increased. Since survival of wild fish (measured by monitoring natural spawners) remained high, it was concluded that released fry were not unduly affecting natural fry. In contrast, survival rates of fry released during spring in the Eagle decreased each year, and the only year the rate of return of natural spawners was above replacement levels was 1985. In other years it appeared that the combination of hatchery plus natural production exceeded the freshwater carrying capacity of the system. The Salmon River has severe water use problems. Most of the natural spawning occurs in the lower river. Survival rates for enhanced fed fry introduced in the upper river were approximately twice those of fry introduced in the lower river suggesting that there may be underutilized habitat above the area with water use problems (Pitre and Cross 1993).

It was concluded that fry releases may be a useful supplementation strategy when progeny from natural spawning do not fully occupy available habitat. However, in instances when numbers of natural fry were underestimated, enhanced fry releases may have adversely affected naturally produced fry (Perry 1995, Pitre and Cross 1993). In these instances, smolt releases were determined to be a more appropriate strategy if coho enhancement was desired.

Stream carrying capacities need to be assessed to identify the need for fry releases. After this type of assessment, coho enhancement in the Eagle River was discontinued. Fry continue to be released in the Coldwater River and in upper areas of the Salmon River where interactions between wild and enhanced coho are judged to be minimal.

Enhancement efforts currently focus on rebuilding depressed stocks and obtaining assessment information that can be used for both wild and enhanced stocks. For the most recent three years available (1995-1997 broods), an average of 193,000 fry and 213,000 smolts were released (Table 6). Many populations are severely depressed, and availability of broodstock has limited production. Production is concentrated at Spius Creek Hatchery, tributary of the Nicola River (Fig. 1). Spius Hatchery enhances six coho populations within the Thompson drainage. Fry are released back to their stream of origin. Some fish are held to smolt and tagged for assessment purposes.

A strategic stock enhancement program was initiated in 1998/99 to develop and implement, through local area-based programs, the immediate enhancement of critical Thompson coho populations while maintaining stock integrity and genetic diversity. Future objectives include the development of area-based production plans that focus on habitat restoration and enhancement, stewardship and the utilization of the productive capacity of community and Department operated facilities to strategically rebuild threatened salmon stocks.

Coho populations that are enhanced in the interior Fraser include Bridge, Coldwater, Spius, Deadman, Louis, Lemieux, and Dunn. Additional populations proposed for enhancement include McKinley, Momich, Eagle, Danforth, Duteau, and Middle Shuswap. It is proposed that fry be released into sections of streams judged to be less than adequately seeded naturally, always within streams of origin. Marking (thermal or CWT) will allow for the future identification of enhanced fish. Increased monitoring and assessment are also proposed. As a genetic safeguard for stocks of critical conservation concern, cryopreservation of milt is being undertaken for Eagle, Bridge, Middle Shuswap, Duteau, Coldwater and Salmon stocks. Live gene banking (captive brood) is considered a strategy of last resort and is not being considered at this time.

V. Overview of Fisheries and Monitoring Programmes During 1999

Regulatory changes made to salmon fisheries in 1998 and 1999 to conserve coho populations were probably the most significant fishery changes ever implemented within the Pacific Region of Canada (Irvine and Bradford 2000). Fisheries were managed with an objective of zero mortality in Canadian waters on coho stocks of most concern (Thompson in southern BC and upper Skeena in northern BC) plus there was a move towards more selective fishing (DFO 1999). BC fishing areas were categorized into red, special management, or yellow zones based on the anticipated prevalence of stocks of concern (Fig. 5). In southern BC, prevalence was determined by the historical frequency of capture of coho of known Thompson origin, determined from an analysis of CWT data from the Mark Recovery Program (MRP) database plus an assessment of stock distribution from 1998 (Irvine et al. 1999b).

Coho fisheries in Washington State (WA) were also reduced relative to most recent previous years. A selective mark-only recreational fishery was operated in Management Units 5 and 6. In addition, Boldt Treaty and non-treaty troll and gillnet fisheries occurred in Areas 4-6 which were expected to encounter BC coho.

Fishery mortality estimates during 1999

Since most BC fisheries in 1999 were non-retention for coho, few coho were sampled for CWTs. CWT recovery data alone would underestimate mortality in these fisheries in any case because they do not incorporate catch and release mortality. We therefore applied stock composition estimates developed from a DNA-based approach to estimates of coho killed in these fisheries. CWT data were not available from WA fisheries in time for this report, so the DNA-approach was used for WA as well.

Observers were present for most fisheries in BC and coho encounter rates were estimated similar to that described for 1998 (Irvine et al. 1999b). Monitoring of First Nations fisheries in 1999 was more thorough than the previous year. Coho encounter data for WA fisheries were obtained from Washington Department of Fish and Wildlife personnel.

Coho mortalities in BC fisheries were determined by applying standard gear mortality estimates (sport 10%, gill net 60%, troll 26%, and seine 25%) from catch and release experiments to the encounter data. Similar values, provided by American colleagues, were used to estimate the numbers of coho mortalities in selective mark-selective fisheries in Areas 5 and 6 in WA.

Tissue samples were taken from coho caught in most fisheries. A single hole paper punch was used to sample coho caught, and these samples were sent to the molecular genetics lab at the Pacific Biological Station (PBS) for analysis. For the mixed stock analysis, 4 microsatellite loci (Oki1, Oki10, Oki100, and Oki101) and 2 MHC loci (alpha1 and alpha2) were used. For details on sample preparation and DNA extraction of these samples for microsatellite analysis see Small et al. (1998b). Microsatellite loci were sized on an ABI Prism 377 sequencer (B.E. Biosystems). The MHC loci were analyzed using DGGE (Denaturing Gradient Gel Electrophoresis) methods presented in Miller et al. (1999). The coho salmon coast-wide DNA data baseline consists of approximately 22,000 fish from 139 stocks ranging from southeastern Alaska to the Columbia River in the south.

Based upon previous recoveries of CWTs in marine fisheries (Anon. 1994), we developed three baseline sets of populations for estimation of stock compositions in marine fisheries in British Columbia (Appendix 1). These three baselines were developed to account for the likely origin of coho salmon in specific fisheries. To minimize bias, we did not include populations in the baseline if they were rarely if ever encountered in a fishery based upon previous CWT analyses. Stock compositions for fishery samples from areas 14-23 and 28-29 and Washington were estimated with a “southern baseline”. The southern baseline included 82 populations, with populations from Oregon, Washington, the Fraser River, Vancouver Island and the southern mainland included in the analysis. Stock compositions for fishery samples from Areas 6-13 and 24-27 were estimated with a “northern baseline” that included all populations surveyed except those from southeast Alaska. Stock compositions for samples from Areas 1-6 were estimated with a “total baseline” that included all 139 populations in the analysis. Drainage-specific baseline populations were used to estimate stock compositions in freshwater test fisheries in the Fraser River.

Maximum likelihood estimates (MLE) of stock grouping contributions were produced using the Statistics Program for Analyzing Mixtures (SPAM). Mixtures and the baseline were bootstrapped 100 times to generate standard deviations about each point estimate.

Estimated stock compositions (Appendix 2) were applied to estimates of 1999 coho mortalities to calculate the number of coho mortalities for the following populations: Thompson; non-Thompson interior Fraser (UFr); lower Fraser (below Hells Gate); East Coast Vancouver Island (Vancouver Island portion of Area 13, Area 14, and Areas 17-19); Southern Mainland (Areas 12 and 13, excluding Vancouver Island; Areas 15 – 16; Area 28); North Coast Vancouver Island (Area 27 and Vancouver Island portion of Area 12), and West Coast Vancouver Island (Areas 20 – 26). We used stock composition results from 1999 samples whenever possible. If we did not have an adequate sample size from the same or a nearby 1999 fishery during the same or similar time period, we used stock composition estimates from 1998 sampling (Appendix 2 in Irvine et al. 1999b). Our target sample size was 200, although this target was not achieved in all strata (Appendix 2). Increased precision of the estimates in those strata of particular management interest can be achieved by increasing sample size or increasing the number of loci used in the analysis.

Sampling of the fisheries was not random so we have no guarantee that samples were representative. We do not advocate that fisheries should be managed solely on the basis of these results (see Section VIII).

VI. Return Timing of Interior Coho

The timing of fisheries in the Fraser River and in marine approach areas has been adjusted to avoid coho returning to the Interior Fraser. Irvine et al. (1999a) examined pre-1997 CWT data and preliminary 1997 DNA results to provide managers with advice on when Interior coho would and would not be prevalent in the lower Fraser. They concluded that Thompson coho begin to enter the lower Fraser in small numbers in August, increase sharply in mid-September, and continued to be caught through the end of October. The purpose of this section is to update this information.

DNA samples from 1997 were re-analysed using a larger baseline that was not available when these samples were initially run. As well, DNA results from the same test fishery for 1998 and 1999 were available.

Results from the DNA analysis of samples from the Petrunia tangle net fishery in the lower Fraser were reasonably consistent (Table 7). Prior to late September, a large proportion of coho caught in the lower Fraser will likely be destined for the interior, after that, the proportion of coho of interior origin decreases and after early October, it is likely that <5% of the coho caught will be from the interior. A paucity of samples early in the run makes it difficult to determine more precisely when the run begins.

The actual migratory timing of interior coho is better understood from an examination of capture rates of coho from near Yale, a short distance below the Fraser canyon (Fig. 6). In 1998, a fishwheel was in place on 19 September and began catching coho immediately. The vast majority of the run had passed this site by late October although coho were occasionally caught until 19 November. In 1999, we were able to install the wheel earlier than in 1998 but it fished for a shorter duration of the run. The wheel was operational on 8 August and commenced catching coho on the 16th August. Although catch rates fluctuated somewhat thereafter, in general they increased and were still at high levels when the wheel stopped fishing on 4 October (Fig. 6.).

VII. Spawning Escapements

Many of our inferences about the status of interior Fraser coho stocks rely upon spawner escapement data. First Nations, contract, and DFO personnel use a variety of techniques to estimate escapements for ~71 streams in the Management Unit. Some estimates are obtained using a counting fence (with or without mark-recapture), others while drifting a stream in a vessel or by snorkeling, on foot, and from a helicopter. Previous assessments (Irvine et al. 1999a, b) describe these studies in detail.

In 1998 and 1999, more effort was expended to enumerate coho than in previous years. For most systems, two separate escapement estimates were obtained. The first was our best estimate of the true number of coho in the system. The second was what we refer to as a trend estimate which is the probable number of fish that would have been estimated if survey effort had been similar to other recent years. See Irvine et al. (1999b) for details on how these estimates were generated.

Two approaches were used to interpret the data in order to examine escapement trends. The first, an escapement indicator approach, had been used in our previous two assessments and relied on escapement estimates to unenhanced streams with a record of consistent monitoring. The 1999 total trend escapements to 10 North Thompson tributaries showed an increasing trend which is encouraging (Fig. 7). The numbers of spawners in these streams in 1999 exceeded 1998 estimates as well as the parental brood escapement (i.e. 1996). The total trend escapements to 16 South Thompson streams also exceeded the brood escapement, but was less than the number of fish estimated to have returned in 1998 (Fig. 8).

The second approach used data assembled for the most recent forecast document (Holtby et al. 2000). Historical escapement estimates were adjusted upwards based on the ratio between the estimate of the true escapement and the trend estimate. Catches and total returns were estimated using the time series of exploitation results including 1999. Missing values were estimated using a contingency table approach (Holtby et al. 2000).

When results assembled using this adjusted historical data approach are examined (Fig. 9), 1999 escapements to the South and Lower Thompson sub-regions were higher than brood escapements. Only in the Lower Thompson were escapements higher in 1999 than 1998. These adjusted escapement estimates indicated a major decline between the mid-1980's and recent years, similar to the escapement indicator data set.

Estimates of total returns (catch plus escapement) exceeded 300,000 coho in a couple of years (Fig. 10), and are currently less than 20,000. Since return estimates are based on expanding escapement estimates using limited exploitation rate data, they are uncertain. Nevertheless, our conclusion is that returns currently are no more than 10% of their maximum.

We compared our two trend analysis approaches by regressing annual adjusted estimates against the total trend estimate for the South (supplemented by escapement estimates to two large enhanced systems, the Eagle and Salmon) and North Thompson (Figs. 11 and 12). The correlation for the South Thompson was very high (R^2=0.99, Fig. 11). The relationship between the two North Thompson estimation approaches was not as good (R^2=0.74, Fig. 12). While a non-linear approach might fit the latter data set better, we conclude that we are less certain of the true numbers of coho returning to the North Thompson than to the South Thompson.

We have been unable to reliably reconstruct the time series of Lower Thompson escapement estimates prior to 1984. Consequently we have much less confidence in historical data from the Lower Thompson than we do for either the North or South Thompson. We suspect that coho from the Lower Thompson are also doing much less well now than 15 years ago, but our evidence is weak. We have no confidence in the assessment of the status of coho from non-Thompson tributaries.

In 1998 and 1999, escapements to Thompson sub-regions represented 67 and 76% of the escapement to the entire management unit respectively (Table 8). When the DNA approach was used to identify coho caught in the Yale fishwheel, a higher proportion of Thompson fish was estimated, 80 and 85% in 1998 and 1999. This discrepancy between these estimates implies a positive bias in the DNA-based estimates of Thompson fish, or that the escapement data are faulty. Only two populations (McKinley and Bridge) were in the baseline to represent the non-Thompson component in our mixture model. A significant portion of the escapement of coho to the non-Thompson sub-region is from the Nahatlatch River (~67% and 76% in 1998 and 1999 respectively), which enters the Fraser Canyon a short distance above Hells Gate. These fish are not represented in our DNA baseline and should be in order for us to be more confident in our DNA-based estimates of non-Thompson Interior coho.

VIII. Time Series of Marine Survivals and Fishery Exploitations

To calculate exploitation rates for major southern BC population aggregates in 1999, we used the approach documented in last year's assessment (Irvine et al. 1999b). The approach requires an estimate of the numbers of coho escaping fisheries and returning to freshwater to spawn. For the Thompson watershed, coho escapements are determined for all important coho spawning streams. For streams from other areas in southern BC, this is not the case and consequently there is more uncertainty in escapement estimates for other population aggregates.

Exploitation estimates for southern BC coho ranged from 4.5-13.3% (Table 9). These exploitation rates do not include retention mortalities in selective mark-only fisheries in Washington; they also do not include terminal freshwater mortalities that were sometimes quite high for certain enhanced populations. WCVI coho exploitations were lower than other Vancouver Island coho because they were only rarely encountered in WA fisheries. Non-Thompson Interior Fraser (UFr) coho appeared to have the lowest exploitation, but estimates for these fish are less certain than for Thompson coho and are probably biased low. We are uncertain of the numbers of coho returning to various large systems including the Chilcotin watershed (visual estimate on Chilko mainstem only), Quesnel River watershed (visual estimate on Mitchell and fence count on McKinley), Blackwater River system (West Road), Cottonwood system, and Nechako. In addition, as implied earlier, we are uncertain whether coho returning to the Nahatlatch would be identified as interior Fraser coho based on their DNA and this population appears to be the largest currently in the non-Thompson sub-region.

The 1999 fishery exploitation rate on Thompson coho was estimated to be ~9% of which ~3% occurred in BC (Table 9).

Our time series of fishery exploitation rates and marine survival estimates for Thompson coho (Appendix 3) was updated to include information for coho returning in 1999, and also to incorporate some changes resulting from a detailed examination of data for Louis and Lemieux creeks in the North Thompson (Irvine et al. 2000). Marine survival estimates (Fig. 13) are limited and the time series is made up of discontinuous estimates from each of the Thompson sub-regions. Marine survivals appear to have declined since the mid-1980's, a pattern that has been documented for many coho south of northern British Columbia (Coronado and Hilborn 1998).

Uprecedented restrictions in Canadian salmon fisheries commencing in 1997 and increasing in 1998 and 1999 are apparent in our time series of exploitation rates (Fig. 14). Exploitation rates the last two years were much lower than they were previously. Bradford and Irvine (2000) concluded that Thompson coho numbers declined in part because harvest rates since 1989 were often excessive.

IX. Update on Trends in Productivity and Spawner Distribution

In this section we update the assessments made in 1998 and 1999 (Irvine et al. 1999a, b). For consistency, we used the same subset of the escapement time series as before, consisting of data from 10 North Thompson and 16 South Thompson streams that have relatively few missing data, and were unaffected by hatchery activities. We also included the Eagle and Salmon Rivers because historically they were the largest coho streams in the Thompson drainage, and most of the data are from weir programs on these streams. We used the 'trend' estimates for 1998 and 1999 because they allow direct comparison with pre-1998 data.

For 1999 the total number of spawners in the four series (the 10 North and 16 South Thompson streams, plus the Eagle and Salmon) was 10% less than 1998 and was about 20% of the average escapement during the peak of abundance in the 1980's. However, the 1999 total was about double those estimated in 1996 and 1997, the low point in the time series.

We derived annual estimates of the productivity of Thompson coho as $r = ln\ [R_t/S_{t-3}]$, where R_t is recruitment (catch+escapement) and S_{t-3} is the abundance of parent spawners. Thus *r* is a measure of survival from spawner to returning (i.e. prefishery) adult. We calculated *r* for each of the four escapement series, and averaged them to obtain an overall trend for the North and South Thompson area (Fig 15).

There has been an overall decline in *r* since 1984, which has been the root of the decline in Thompson coho (Bradford and Irvine 2000). However, the average *r* for the 1999 returns was 0.59 (SE=0.38), corresponding to an average R/S ratio of 1.8. As a result, recruitment in 1999 was about double the parent escapement of 1996. Because fishing mortality was very low in 1999, escapements increased over the brood year, as noted above. This is fortunate, because the 1996 escapement was the lowest on record, and this brood line might have been irreparably harmed if survival had continued on its downward trend.

While improvement in *r* in 1999 is encouraging, it is still too early to suggest a trend towards improving survival rates. Inspection of Fig. 15 shows that *r* has fluctuated considerably during the overall decline from 1984 to 1999, and the increase in 1999 may just be one of those fluctuations. Thus we do not know if survival will generally continue to trend downward, or if the returns of 1999 represent a reversal of the decline.

As in previous years, we monitored the proportion of streams in which spawners were observed in 1990 but had reached 'none observed' status in 1999, three generations later. This fraction was 18% in 1999, which is slightly lower than previous years (27% in 1998, 32% in 1997). These data suggest that slightly more of the historically used range of Thompson coho was occupied in 1999 compared to the previous last few years. Nonetheless, production from the Thompson drainage is still concentrated in relatively few large streams, and the status of many of the small spawning populations remains poor.

In summary, in 1999, better survival conditions (as reflected in the higher *r*), and fishery restrictions resulted in an improvement in the aggregate status over the brood year. There is insufficient information to determine whether a long-term trend to improving survival is underway. Reference points (e.g. Bradford et al. 2000) have not been established for this management unit, so a formal assessment relative to a standard is not possible. But, the overall abundance remains low, and it is our opinion that the status of the aggregate remains poor. The parent escapement for the 2000 return was only slightly larger than for the 1999 return, so our previously expressed concerns for the status of these populations continues.

X. Role of Freshwater Habitat in the Decline of Thompson Coho Salmon

It is unlikely that the rapid decline in coho abundance in the Thompson drainage in the past 10-15 yrs was due to a simultaneous collapse of freshwater habitat productivity in the whole basin. But, many have noted that significant freshwater habitat degradation has occurred in the region. Habitat alterations could reduce the productivity of coho populations during the freshwater segment of their life, which would render them more vulnerable to overexploitation, especially during periods of poor ocean conditions. Irvine et al. (1999b) recommended that the role of habitat change in the decline of Thompson coho should be examined.

Juvenile coho salmon favour low gradient streams and these streams are often located on valley floors in mountainous regions. These areas are also preferred for agriculture, forestry, urban development, and transportation corridors; all are activities that can impact aquatic habitats. In the Thompson watershed many valley bottoms were initially logged, and subsequently used for agriculture (mainly livestock, dairy, and animal feed crops) for at least 50 years (Burt and Wallis 1997). In some cases, riparian vegetation has been removed and livestock has destabilized stream banks, and off-channel habitats and wetlands have been destroyed or isolated by dyking. In non-agricultural areas the prime old-growth timber on the valley floors has been removed, and now extensive logging is occurring in the headwaters of most watersheds. In addition, much of the southern and western part of the Thompson drainage is in a semi-arid area, and high rates of water withdrawal in summer for irrigation cause low flows and high water temperatures (Rood and Hamilton 1995). Specific habitat concerns, by watershed, have been collated in a series of Fraser River Action Plan (FRAP) reports (e.g., Harding et al. 1994, DFO 1998 a, b).

Recently, Bradford and Irvine (2000) related the rate at which the abundance of coho returning to individual spawning streams has declined to the extent of human activity in the corresponding watershed. The hypothesis being tested was that the rates of decline (for years 1988-1998) in individual spawning populations would be negatively related to land use in the catchment. It was assumed that all spawning populations were experiencing the same rates of fishing and ocean mortality so that variability among spawning populations might be related to freshwater productivity. Bradford and Irvine used four measures of land use, and showed that the rates of decline in individual spawning populations were related to three of them (Fig 16).

Land use patterns may be one reason why the abundance of spawners in the South Thompson has declined at a greater rate than those of the North Thompson have. Watersheds in the South Thompson are more impacted by human activities; average scores for the three measures of land use that are correlated with coho declines (Fig. 16) were higher for the South than the North Thompson basin.

Productive freshwater habitats can help sustain salmon populations during periods of adverse marine conditions (or overexploitation) because they maximize the number of smolts produced per female spawner. The analysis of Bradford and Irvine (2000) shows that spawning populations are at greater risk when the watershed is subject to extensive human modification. Those populations from healthy watersheds showed the smallest declines, and are likely to recover at a faster rate if ocean conditions improve. Thus, the recovery and sustainability of North and especially South Thompson coho will be improved through a balanced program of habitat protection and watershed restoration. While data limitation prevented us from conducting a similar analysis for other interior Fraser coho populations, it is likely these conclusions are equally valid for the whole region.

XI. Conclusions

1. The total exploitation rate on interior Fraser coho salmon in 1999 was ~9%, (~3% Canadian, ~6% US fisheries) which is largely unchanged from 1998, but substantially less than in earlier years.

2. Total 1999 spawning escapements to North and South Thompson streams were similar to those observed in 1998. But the 1999 escapement was nearly double the 1996 brood escapement, which was the lowest on record. The survival of fish returning in 1999 was better than for 1997 or 1998. However, given the historical variability in survival, it is premature to suggest that this is a trend to conditions more favourable for coho salmon. We have no basis to alter the conclusion reached in this year's forecast document (Holtby et al. 2000) that it is unlikely that stock size will increase in 2000.

3. Estimates of total interior Fraser aggregate recruitment or escapement in 1999 were about the same as 1998. Formal reference points for evaluation of stock status do not yet exist. Thus we use the observations that (1) total recruitment is only 10% of that observed 10-15 years ago, and (2) in many streams spawners are absent or in very small numbers to conclude (as in 1998) that the status of the stock aggregate remains poor.

4. Non-Thompson Interior coho appear to have the same genetic origin as Thompson coho, and it would appear that they should remain in the same management unit. Genetic analysis suggests genetic differentiation in fish from major drainage basins, but little among fish in tributaries within basins.

5. Traditional ecological knowledge, whether from aboriginal people or non-aboriginal people may be useful in improving our understanding of interior coho. However, assembling and interpreting this information will be a large task and there is no mechanism to do the work. Before being used in a stock assessment, TEK will need to be appraised for accuracy and reliability similar to other information used in a scientific document.

6. Interior Fraser coho enter the lower Fraser River in late August and almost all appear to have entered the Fraser canyon area by late October.

7. A quantitative analysis of land use patterns in Thompson basin watersheds suggests that habitat alteration caused by human activities played a role in the decline of the aggregate although high exploitations during years of low survival were a more significant factor. More intensive land use in the South Thompson may explain why declines in these populations have been more severe than in the North Thompson.

XII. Recommendations

1. Target and limit reference points for Interior Fraser River coho are needed to provide management advice relative to current abundance levels and forecast trajectories.

2. A policy on the role and evaluation of strategic enhancement in restoring declining populations such as the Thompson needs to be formulated.

3. More extensive coverage of the interior Fraser region for genetic sampling will aid in the delineation of populations.

4. The upstream boundary of the management unit for interior Fraser coho should be extended upstream to include the known range of interior Fraser coho.

5. Since non-Thompson coho are distinguishable from Thompson coho, and since our information on their status in highly uncertain, it is beneficial to separate these populations from each other in marine fisheries in order to estimate exploitation rates.

6. The largest population of non-Thompson Interior coho is from the Nahatlatch River, yet these fish are not in our baseline of genetic data. Since this river enters the Fraser canyon only a short distance above Hells Gate, Nahatlatch coho may be different from other Interior Fraser coho. Tissue samples should be gathered and analysed from Nahatlatch coho.

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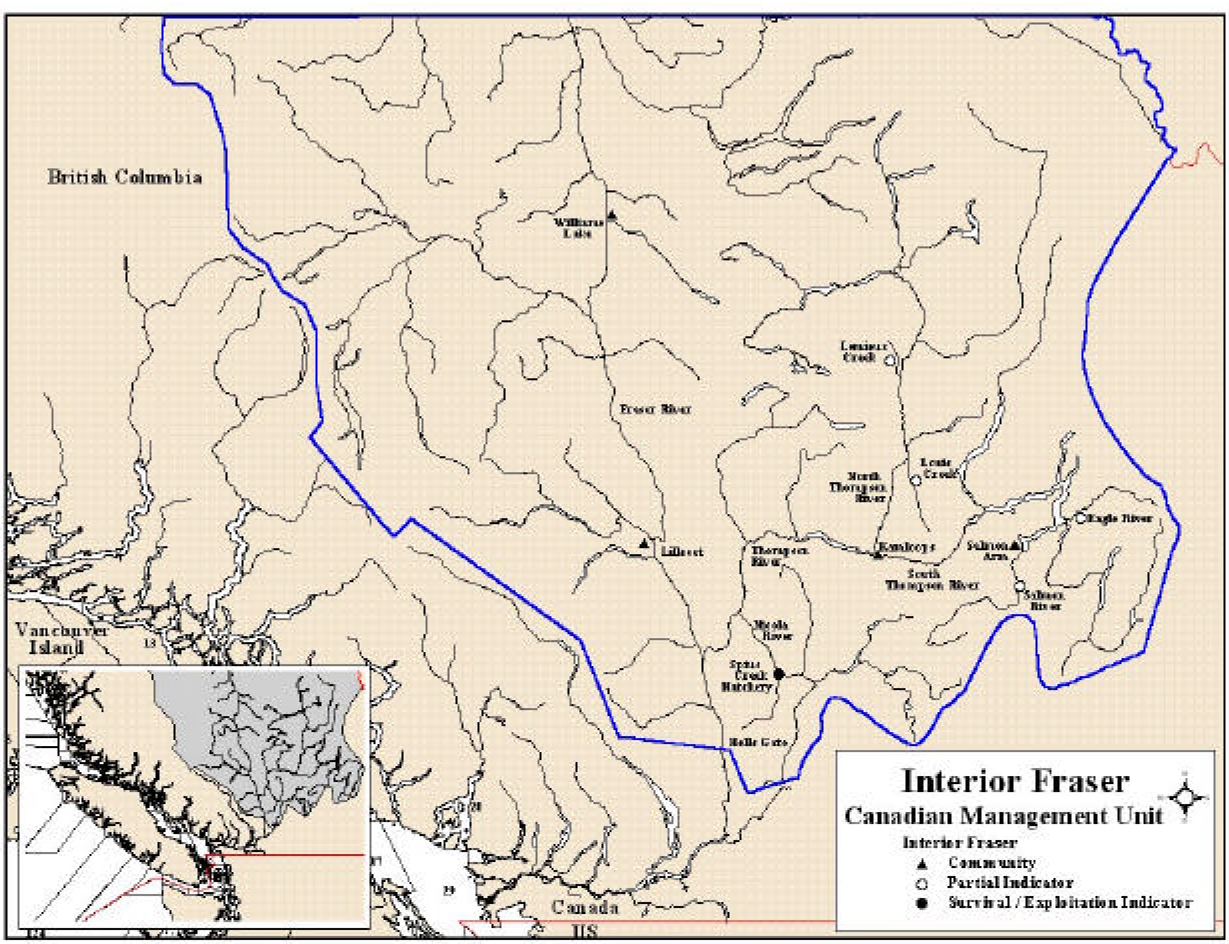


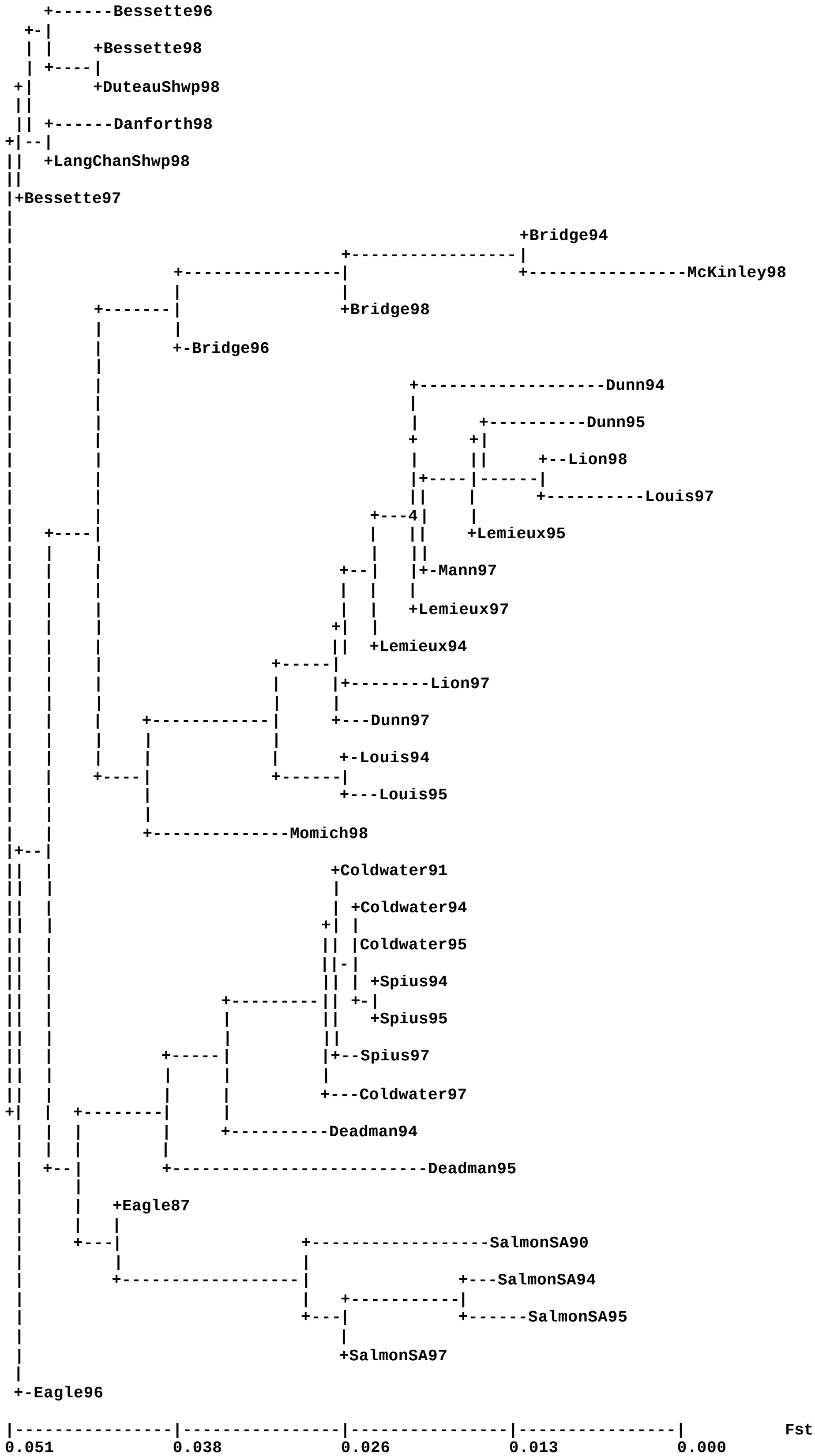
Figure 1. Map of Interior Fraser coho management (i.e. conservation) unit. Inset show location of unit within southern British Columbia.

Figure 2. Neighbor joining dendrogram of Fraser River coho salmon based on Fst values calculated from seven microsatellite loci and one MHC class I locus.

```
    +-Alouette
    |
    |--------Chilliwack
    |
    |------SalmonLF
    |
+---|+---Chehalis
|   ||
|   || +-------Kanaka
|   || |
|   +|  +Stave
|    | |+|
|    | ||   +--------------U.Pitt
|    | ||
|    | ||                                               +Bridge                  Upper
|    +-||                               +----------------|                     Fraser
|      ||                               |                +------------McKinley
|      ||                               |
|      ||                               |                   +Bessette
|      ||                               |                  +|
|      ||                               |                 +|--DuteauShwp
|      ||                              +|                 ||                  Shuswap
|      +|                              ||              +-||---Danforth
|       |                              ||              |  |
|       |                              ||    +---------|  +LangChanShwp
|       |                              ||    |         |
|       |                              ||  +-|         +Eagle        South Thompson
|       |                        +-----||  | |
|       |                        |      |+---|-------Momich             Adams
|       |                        |     |   |
|       |                        |     |   +--------------------SalmonSA     South
|       |                        |     |
Thompson
|       |                        |     |                 +Coldwater
|       |                        |     |         +------------|
|       +------------------------|     +---------|            +-Spius         Lower
|                                |               |
Thompson
|                                |               +-------Deadman
|                                |
|                                |          +Dunn
|                                |       +--|
|                                |       |  |-Lemieux
|                                |       |  +                North
|                                +-------|  |  +-Lion        Thompson
|                                        |  +--|
|                                        |     +Mann
|                                        |
|                                        +---Louis
|
|    +----Inch
|   +|
+---|--Norrish
    |
    +--Nicomen

|----------------|----------------|----------------|----------------|
0.082            0.062            0.041            0.021            0.000
                                 Fst
```

Figure 3. Neighbor joining dendrogram of samples of Upper Fraser and Thompson River coho salmon based on Fst values calculated from seven microsatellite loci.



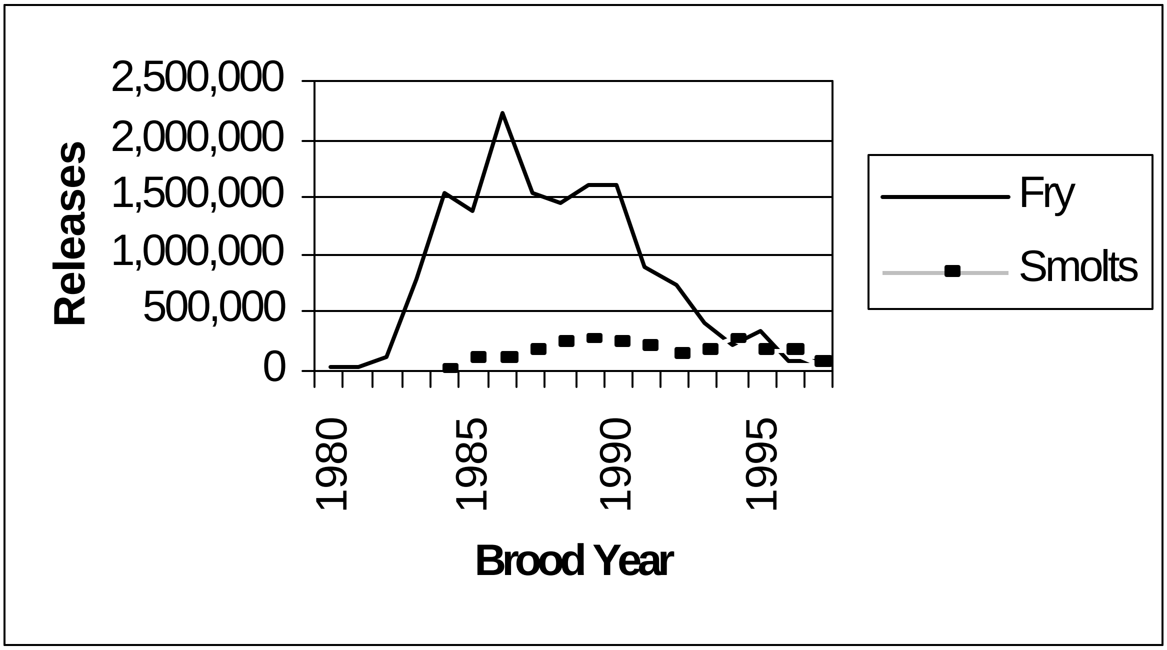
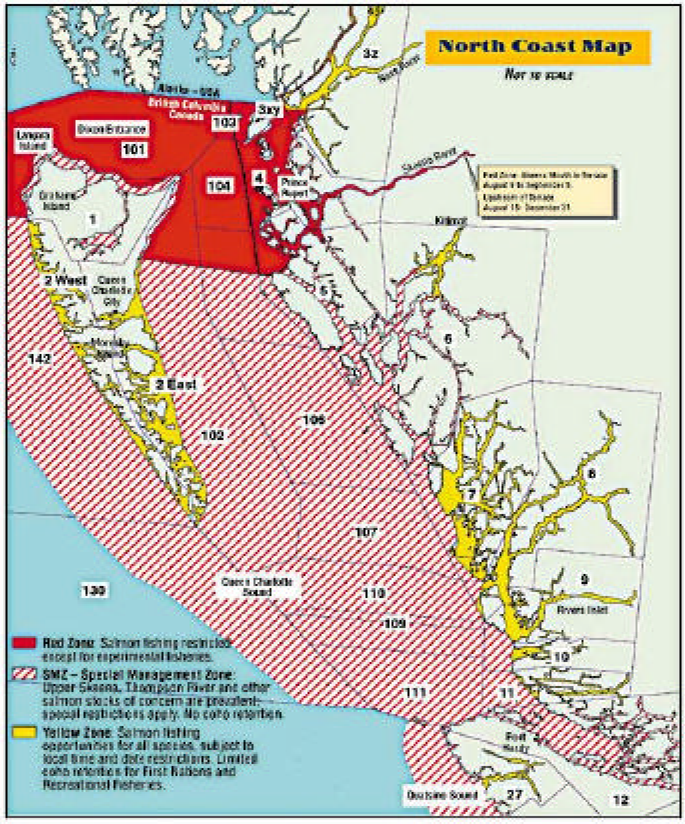


Figure 4. Summary of fry and smolt releases to streams in the Interior Fraser Management Unit.



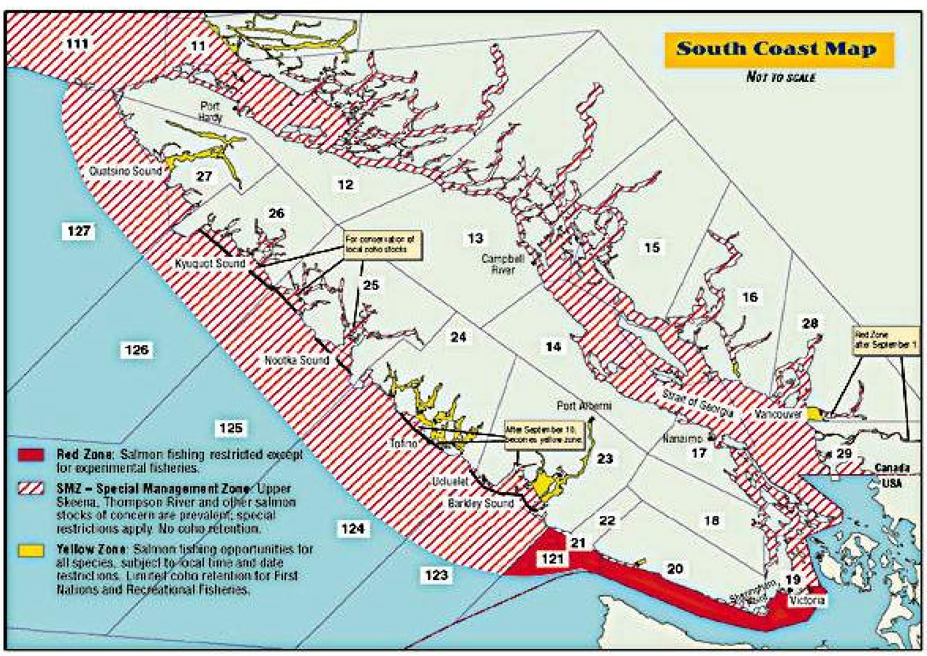


Figure 5. Red, special management, and yellow zones for North and South coast salmon fisheries in 1999.

Adult Coho Catches at Yale Fishwheel

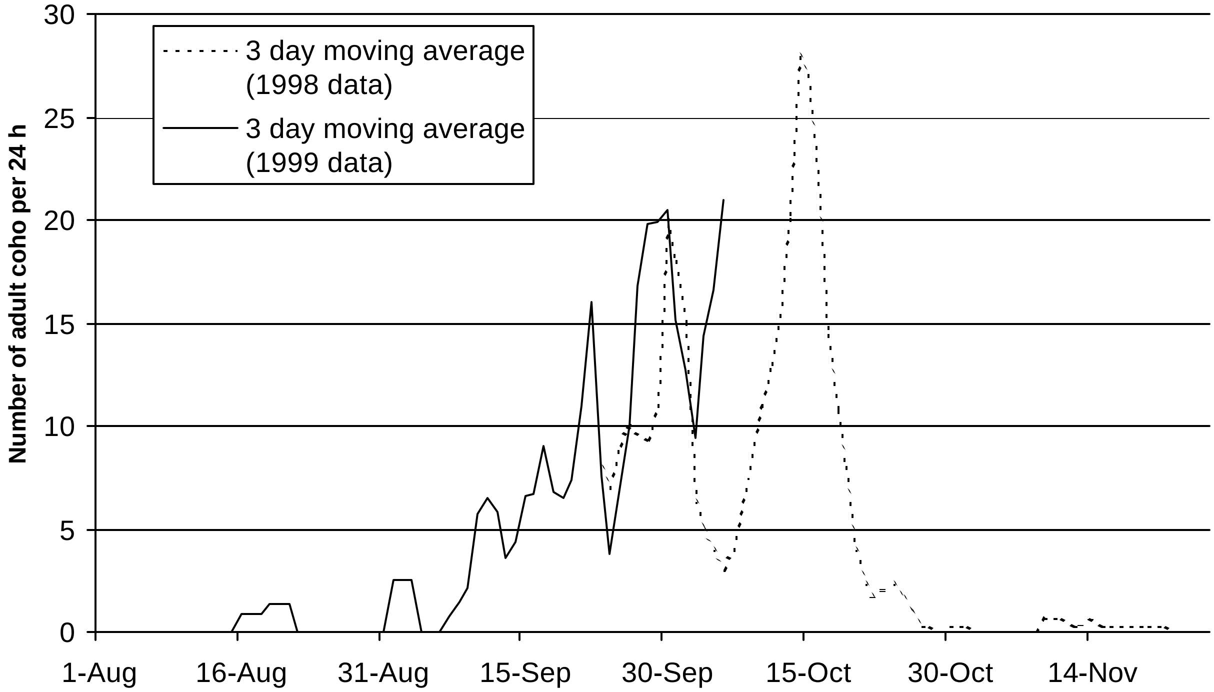


Figure 6. Number of coho/24 h period (3 d moving averages) for 1998 and 1999. In 1998 the wheel was fished 24 h/day, while in 1999 the wheel was fished for partial days and 24 h catches were estimated based on the proportion of the day spent fishing.

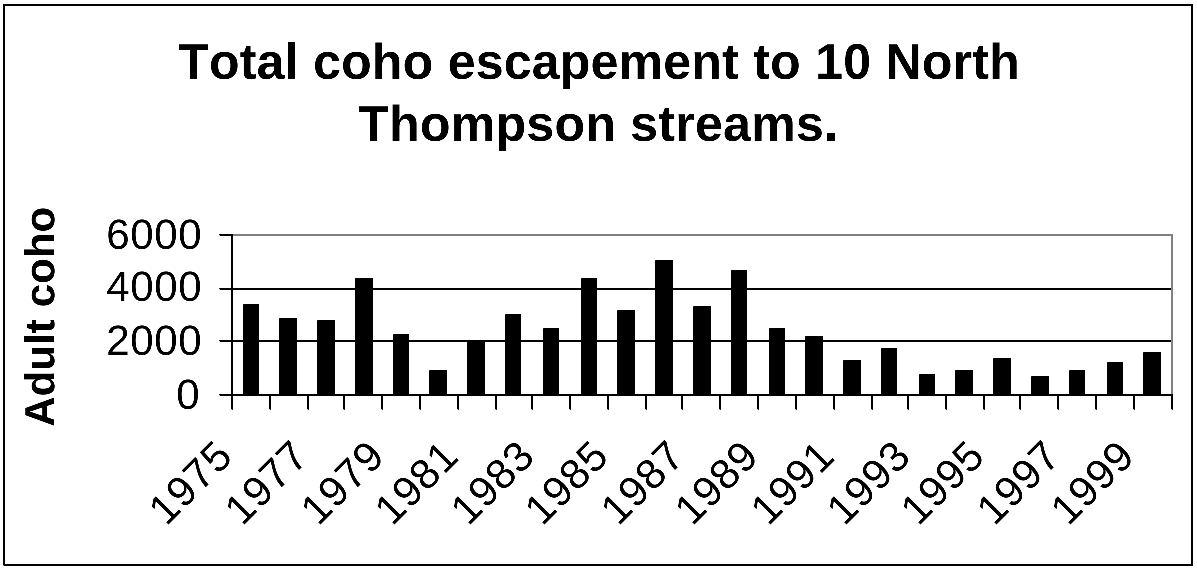


Figure 7. Total coho escapement to 10 North Thompson escapement indicator streams.

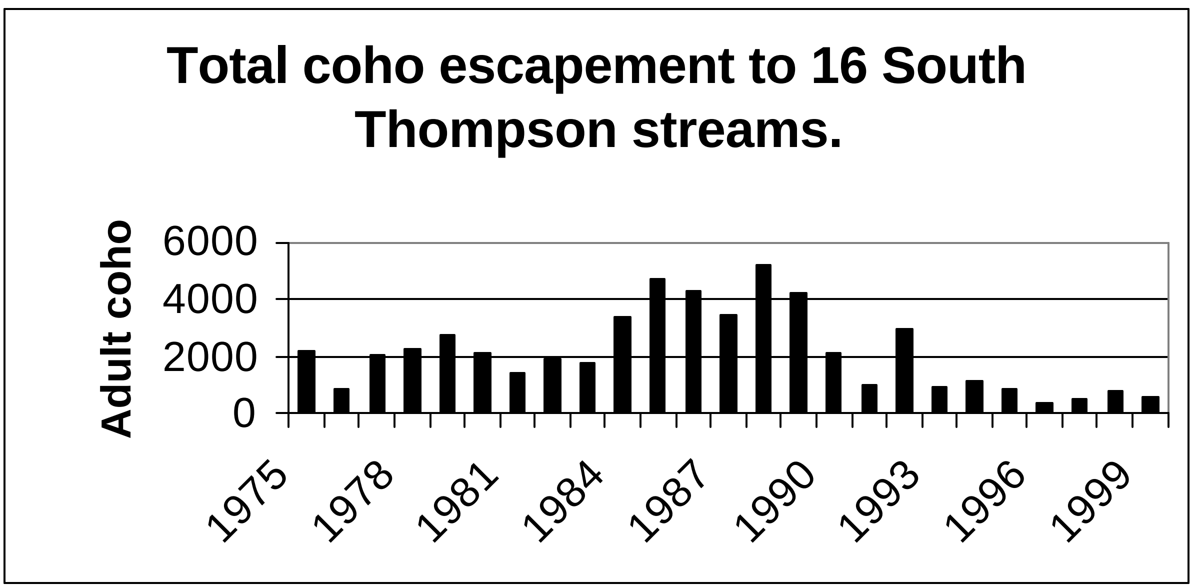


Figure 8. Total coho escapement to 16 South Thompson escapement indicator streams.

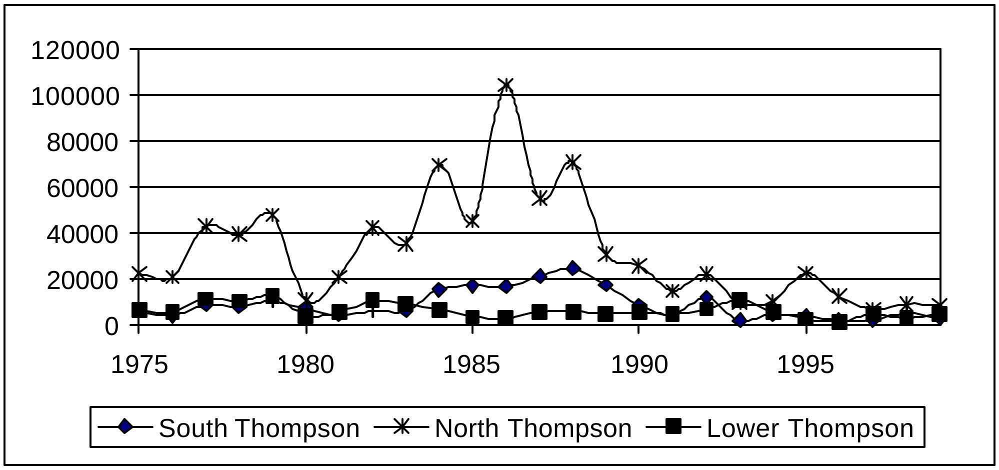


Figure 9. Adjusted historical escapement estimates to three Thompson sub-regions.

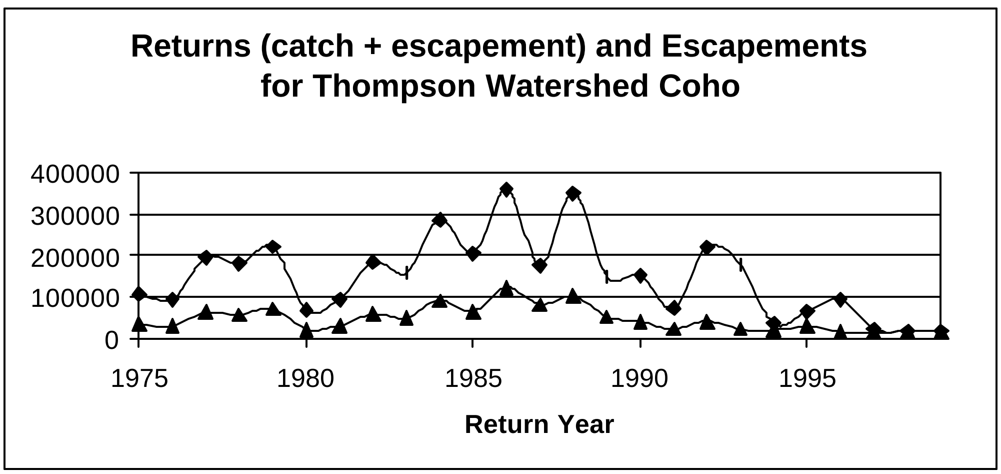


Figure 10. Total returns and adjusted escapement estimates for entire Thompson watershed.

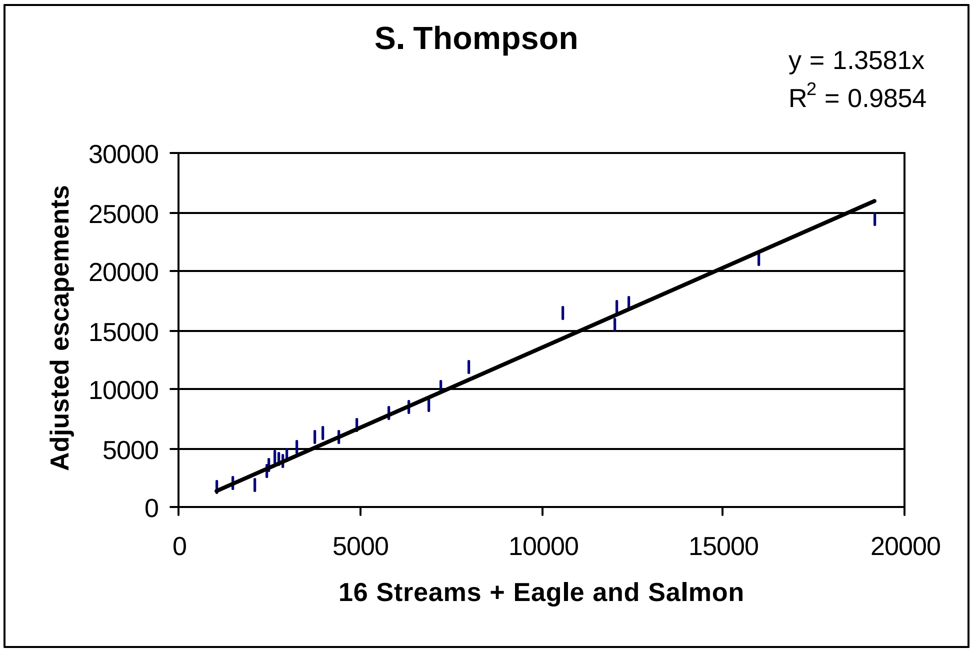


Figure 11. Regression between South Thompson total trend escapements plus escapements to the Eagle and Salmon rivers and the adjusted historical South Thompson escapements.

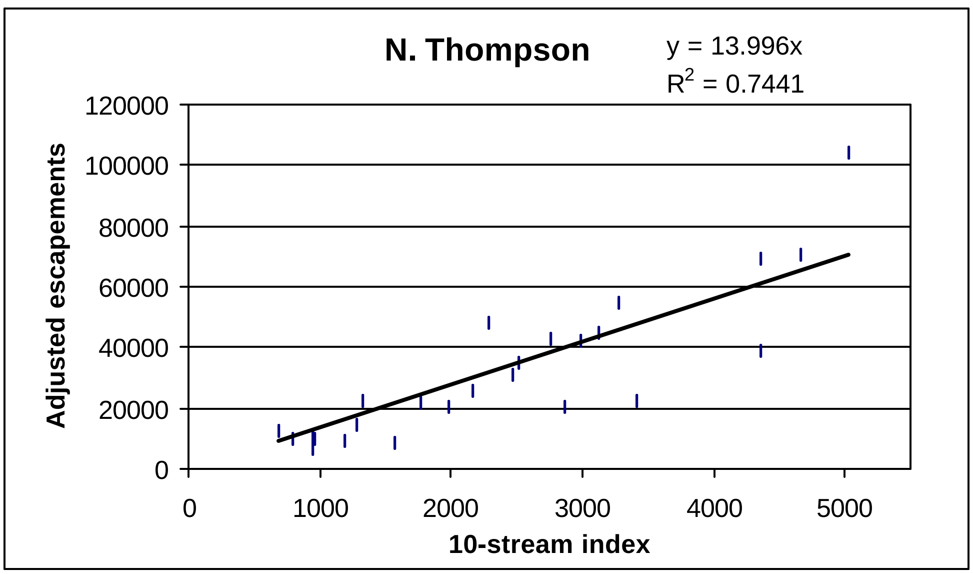


Figure 12. Regression between North Thompson total trend escapements and adjusted historical North Thompson escapements.

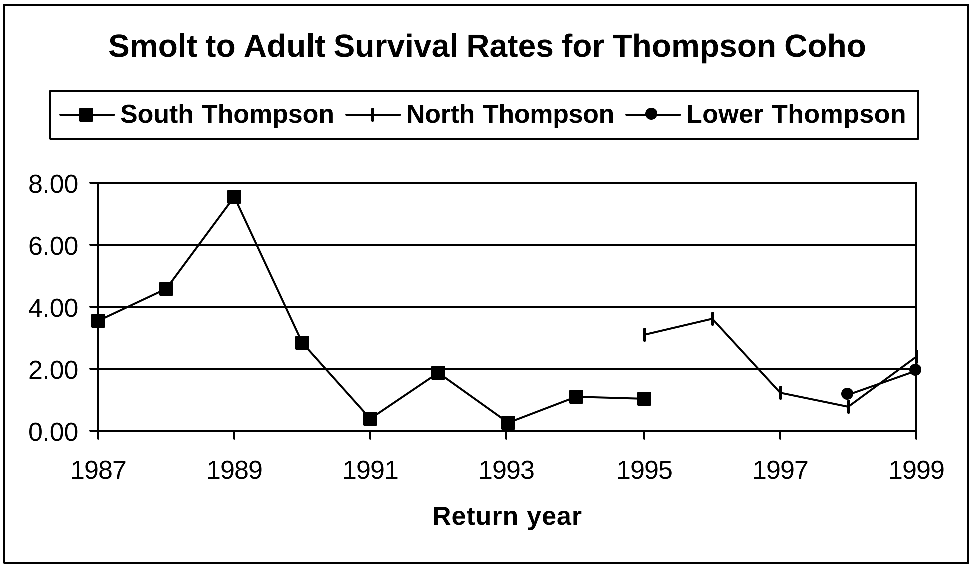


Figure 13. Smolt to adult survival estimates for coho from the Thompson River watershed. North Thompson estimates are biased low because stray escapements, known to have occurred, were not included in the calculations and these were sometimes significant.

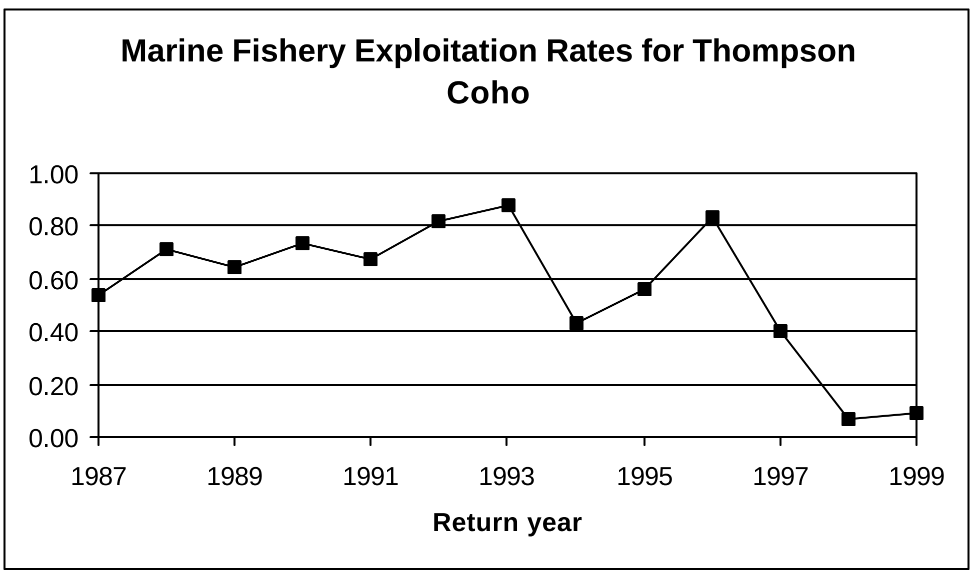


Figure 14. Exploitation rate estimates for Thompson watershed coho.

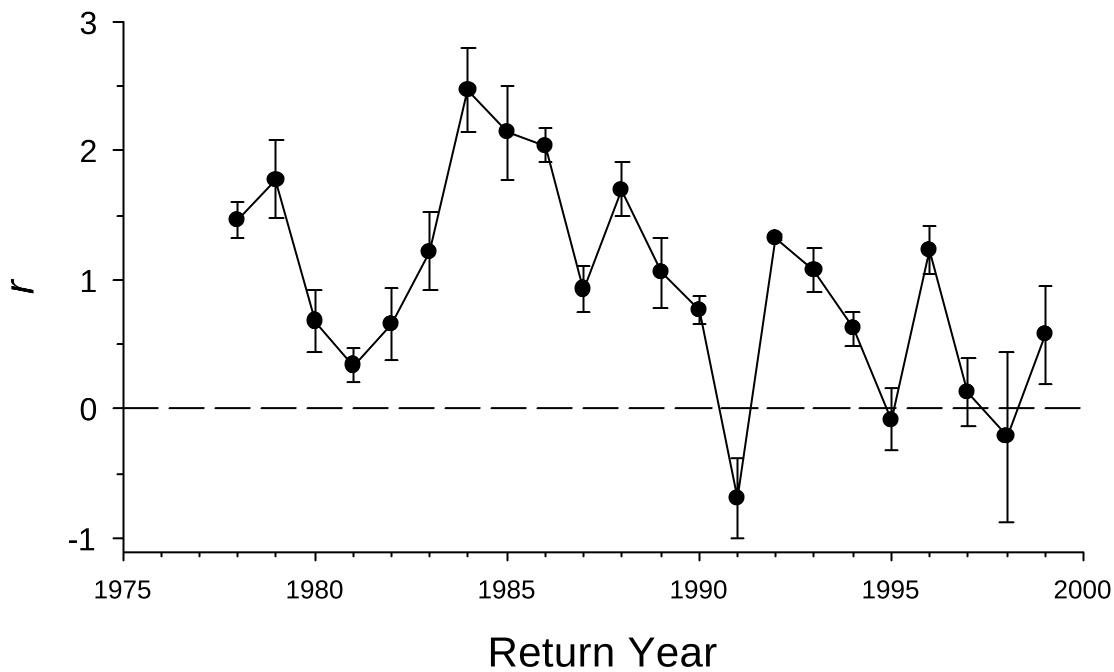


Figure 15. Time series of *r,* the intrinsic rate of population growth of Thompson coho salmon. Each point is the average (±SE) of four time series (North and South aggregates, Eagle and Salmon). When *r* < 0 the populations are unable to replace themselves, even in the absence of fishing mortality.

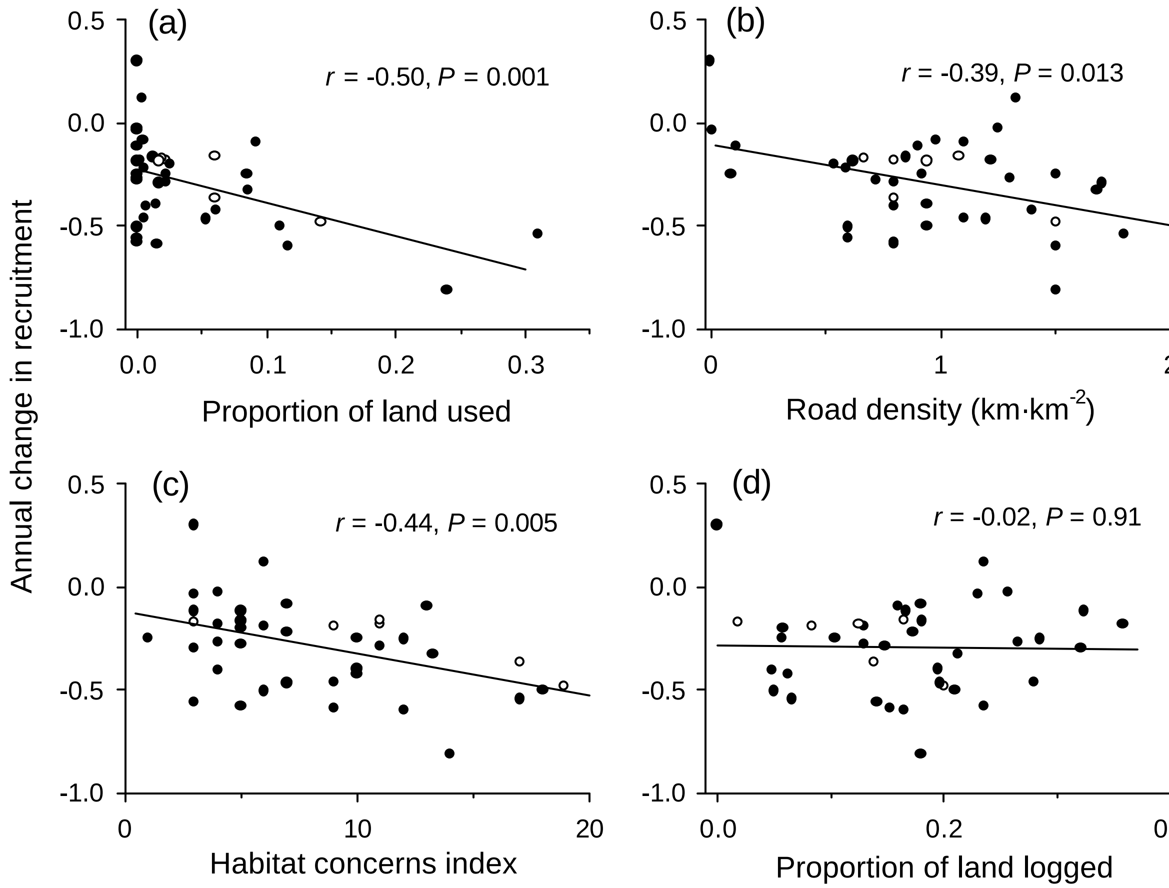


Figure 16. Relations between four land use measures and the rate of decline ($year^{-1}$) in the recruitment of coho salmon to 40 Thompson tributaries (from Bradford and Irvine 2000). (a) the proportion of land in each catchment dedicated to agricultural or urban use, (b) the density of forest, agricultural and hard surface roads in each catchment, (c) a semiquantitative index of habitat concerns from FRAP reports (see Bradford and Irvine 2000), and (d) the proportion of land recently (<20 years) logged. Open circles are streams that have had hatchery programs.

Table 1. Sample sizes by location and year of Thompson River and Upper Fraser coho analyzed at microsatellite and MHC loci.

Location	1987	1990	1991	1994	1995	1996	1997	1998	Total
Lower Thompson									
Coldwater			30	84	92		32		238
Spius				82	96		105		283
Deadman				15	50				65
North Thompson									
Dunn				25	24		34		83
Lemieux				60	66		46		172
Louis				24	46		21		91
Lion							24	18	42
Mann							58		58
South Thompson									
Eagle	47					140			187
Salmon River		15		30	63		11		119
Shuswap									
Bessette						56	45	76	172
Danforth								30	30
Duteau								37	37
Lang Channel								59	59
Adams									
Momich								38	38
Upper Fraser									
Bridge				40		32		51	123
McKinley								165	165
Total									1962

Table 2. Fst and Nei's 1978 genetic distance values for pairwise comparisons of coho salmon samples within and among three regions of the Fraser River. Standard deviations are in parentheses. Values in the final column are a comparison of the pooled Lower Fraser and pooled Upper Fraser/Thompson (interior) samples.

	Pairwise comparisons of tributaries within watersheds			Pairwise comparisons of tributaries between watersheds			
	Among Lower Fraser tribs	Between Upper Fraser tribs	Among Thompson tribs	Between Lower Fraser and Thompson	Between Lower and Upper Fraser	Between and Thompson and Upper Fraser	Between pooled LFraser and Interior
Fst							
Micros	0.015 (.005)	0.016	0.031 (.015)	0.055 (.011)	0.071 (.018)	0.046 (.017)	0.034
MHC	0.021 (.010)	0.001	0.068 (.049)	0.155 (.056)	0.154 (.025)	0.050 (.032)	0.120
Nei's							
Micros	0.087 (.033)	0.046	0.128 (.064)	0.290 (.062)	0.339 (.068)	0.178 (.06)	0.196
MHC	0.183 (.097)	0.000	0.204 (.160)	1.077 (.387)	1.084 (.373)	0.148 (.114)	0.859

Table 3. Hierarchical gene diversity analysis of Fraser River coho salmon sampled from 24 sites and surveyed at seven microsatellite loci and one MHC class I locus.

	Absolute diversity		Relative diversity			
Locus	Total	Within samples	Within samples	Among trib/year Within basins	Among basins within regions	Between upper and lower regions
Oki1	0.7999	0.7423	.928	.011	.031	.031
Oki10	0.9098	0.8561	.941	.011	.019	.029
Oki100	0.9406	0.9034	.960	.014	.016	.010
Oki101	0.8591	0.7909	.921	.011	.031	.037
Ots2	0.5319	0.5060	.951	.015	.033	.001
Ots3	0.7352	0.6645	.904	.016	.025	.055
Ots101	0.9053	0.8367	.924	.008	.015	.053
Overall	5.6818	5.300	.933	.012	.024	.032
MHC	0.7670	0.6162	.803	.013	.062	.121

Table 4. Hierarchical gene diversity analysis of Thompson River coho salmon sampled from 13 sites and surveyed at seven microsatellite loci and one MHC class I locus.

	Absolute diversity		Relative diversity			
Locus	Total	Within samples	Within samples	Among years within tribs	Among tribs Within basin	Among basins
Oki1	0.8202	0.7853	.957	.009	.002	.031
Oki10	0.8966	0.8745	.975	.004	.007	.013
Oki100	0.9350	0.9100	.973	.007	.008	.011
Oki101	0.8493	0.8161	.961	.007	.005	.027
Ots2	0.4859	0.4509	.928	.006	.019	.048
Ots3	0.6896	0.6562	.952	.006	.009	.033
Ots101	0.8944	0.8633	.965	.006	.013	.015
Overall	5.6711	5.3571	.962	.006	.009	.023
MHC	0.6932	0.6177	.891	.006	.008	.094

Table 5. Genetic diversity associated with tributaries and years for samples of coho salmon from the North Thompson and Nicola rivers.

	Absolute diversity		Relative diversity		
River	Total	Within samples	Within samples	Among years within tribs	Among tribs
N. Thompson					
microsatellite	5.5249	5.4559	.988	.008	.003
MHC	0.7571	0.7394	.976	.023	0.0
Nicola					
Microsatellite	5.7014	5.6818	.997	.002	.001
MHC	0.5784	0.5757	.995	0.0	.005

Table 6. Numbers of coho fry and smolts released 1995-1997 brood years.

Project	Donor Stock	Release Site	1995 Fry	Brood Smolts	1996 Fry	Brood Smolts	1997 Fry	Brood Smolts
Spius Creek	Salmon R/TOMF	Salmon R/TOMF	129742		15235	15657	1290	2380
Kamloops School	Louis Creek	Chase Creek					200	
Armstrng/Shswp School	Salmon R/TOMF	Salmon R/TOMF	450		800			
Revelstoke School	Salmon R/TOMF	Salmon R/TOMF	350		400			
Vernon School	Salmon R/TOMF	Salmon R/TOMF	300		300			
Kingfisher Creek/TOMF	Salmon R/TOMF	Salmon R/TOMF	4500					
Shuswap R	Bessette Creek	Duteau Creek				12460		
Spius Creek	Coldwater R	Coldwater R	151188	12368		26840	4952	51980
	Spius Creek	Spius Creek	59925	137392	56941	86324	63603	23546
Bridge R	Bridge R	Bridge R	8500		13500		11500	
Merritt School	Coldwater R	Coldwater R	150		250		160	
Deadman R	Deadman R	Drainy Ch	11000					
		Deadman R				32748	10000	33850
Gold Trail School	Bridge R	Bridge R	250		400			
		Cayoosh Creek					490	
	Deadman R	Deadman R			80			
		Cayoosh Creek					240	
Spius Creek	Lemieux Creek	Lemieux Creek				6936		
	Louis Creek	Louis Creek			166			
Kamloops School	Lemieux Creek	Lemieux Creek	200					
		Raft R			200			
		Clearwater River (lwr)					240	
	Louis Creek	Tranquille R	2000		2300		2300	
Thompson R N	Lemieux Creek	Lemieux Creek						26892
		Ianson Ch		20000				
	Louis Creek	Louis Creek						13898
	Dunn Creek	Dunn Creek		26000				
		Dunn Lk						26346
		Total	**368555**	**195760**	**90572**	**180965**	**94975**	**178892**

Table 7. Relative Composition (Percentages) of interior Fraser coho from DNA analysis of tangle net samples from the lower Fraser River (1997-1999).

	1997		1998		1999	
	n	%	n	%	n	%
Before 22 Sept	127	35.0	59	73.4	179	41.4
23 Sept - 2 Oct	244	21.6	122	13.5	66	18.5
3-8 Oct	38	4.3	79	4.3	56	6.2
9-15 Oct	123	2.8	247	3.2	82	6.5
16-22 Oct	42	3.4	254	0.4	163	2.7
23 Oct-15 Nov	18	0	146	0.6	76	3.2

Table 8. Summary escapement estimates (including brood stock taken) to Thompson and non-Thompson subregions compared with estimates from DNA analysis of coho samples from Yale fishwheel.

	1998	1999
Thompson escapement	16395	16614
Non-Thompson escapement	8147	5389
Non-Thompson escapement minus Nahatlatch escapement	2687	1293
Percent of entire Management Unit escapement that were Thompson	66.8	75.5
Percent of coho caught at Yale that were Thompson (Appendix 2)	80.0	84.6

Table 9. Summary estimates of 1999 escapements, fishery mortalities (morts), and exploitations for southern BC coho populations in fisheries in Alaska, northern and central BC, southern BC, and Washington (Wa) State [1].

	Thompson	WCVI	ECVI	NVI	SoMnLnd	LFr	UFr
Approximate Escapement	17,000	285,000	70,000	45,000	145,000	92,000	5,400
1999 Alaska Exploitation [2]	0.003	0.000	0.007	0.007	0.007	0.003	0.003
N/Central Coast Morts	80	2019	1879	1716	6591	1213	28
1999 N/Central Exploitation	0.005	0.007	0.026	0.037	0.043	0.013	0.005
Southern BC Morts	353	12,120	3,191	1,954	2,300	4,365	148
1999 SBC Exploitation	0.020	0.041	0.044	0.042	0.016	0.045	0.027
Wa Mort's [3]	1164	2461	4228	1328	4047	7157	56
1999 Wa Exploitation	0.064	0.009	0.057	0.029	0.027	0.072	0.010
Total Fishery Exploitation [4]	0.092	0.057	0.133	0.114	0.093	0.133	0.045

[1] WCVI = West Coast Vancouver Island, ECVI = East Coast Vancouver Island, NVI = Northern Vancouver Island, SoMnLnd = Southern Mainland (non-Fraser), LFr = Lower Fraser, and UFr = Upper Fraser (non-Thompson)

[2] Obtained from MRP estimates for 1999 returns. WCVI estimated from releases from Robertson Creek; ECVI the mean exploitation from Quinsam and Big Qualicum; LFr the mean of Chilliwack and Inch Creek. Thompson and UFr assumed to be the same as LFr; NVI and SoMnLnd assumed to be same as ECVI.

[3] Does not include retention mortalities in mark only fisheries in US Areas 5 and 6.

[4] Does not include terminal freshwater exploitations which can be high for some enhanced populations (e.g. Chilliwack, Inch, and Quinsam).

Appendix 1 - Coho salmon baselines by stocks and regional grouping used in DNA mixed stock analysis.

Baseline	**N**	**Regional groupings and stocks**
Fraser	27	*UPFR*:Bridge,Mckinley;*Thompson*:Bessette,Coldwater,Danforth,Deadman,Dunn,Duteau,Eagle,LangChannel,Lemieux,Lion,Louis,Mann,Momich,Salmon@SA,Spius;*LWFR*:Allouette,Chehalis,Chilliwack,Inch,Kanaka,Nicomen,Norrish,Salmon@LF, Stave,Upper Pitt.
Southern	82	All of the above plus *NCVI:*Cluxewe,GlenLyon,Nahwitti,Nimpkish,Quatse,Stephens,Washlawis,Waukwaas;*WCVI:*Conuma,Craigflower,Cypre,Kennedy,Kirby,Kootowis,Nitinat,Pachena,Robertson,SanJuan,Sarita,Sooke,Tranquil;*ECVI*:BigQualicum,Black,Chemainus,Cowichan,Goldstream,Nanaimo,Puntledge,Quinsam;*SouthernMainland:*Capilano,Homathko,Lang,Seymour,Sliammon,Squamish,Devereux*,Klinaklini*;*PugetSound*:HoodCanal,Grizzly,Marblemount,Minter,Nisqually,Nooksack,Wallace;*JuandeFuca*:Dungeness,Elwha;*Coastal*:Bingham,Clearwater(US),Queets,Quillayute,Shale,Willapa;*Columbia*:Clackamas,Cowlitz,Lewis.
Northern	130	All of the above plus *QCI*:Tasu,Copper,Deena,Pallant,Awun,Sangan,Yakoun;*Nass*:Meziadin,Tseax,Zolzap;*UpperSkeena:*Babinefence,Boucher,UpperBabine,Bulkley,Morice,Owen,Toboggan,Kluatantan,Motase,Sicitine,Slamgueesh,Sustat;*LowerSkeena:*Clear,Coldwater@SK,Deep,Clearwater,Exchamsiks,Hadenschild,Kalum,Kasiks,Schulbackhand,Sockeye,Zymagotitz,Kispiox,Kitwanga,Singlehurst;*North/CentralCoast*:Ecstall,Green,Lackmach,Atnarko,Docee,HartleyBay,Kitasoo,Kitimat,Mclaughlin,Salloomt,Sheemahant,Thorsen.
Total	139	All of the above plus *S.E.Alaska*:Berners,Gastineau,HiddenFalls,HughSmith,IndianCr.,Karta,Margaret,Reflection,WhitmanLake.

* Stocks Klinaklini and Devereux in North/Central Coast regional group for Northern and Total baseline.

Appendix 2 Coho DNA mixed stock estimates for 1999 sampling. N= number of fish in sample (N)= number of unique genotypes in sample. Standard deviations given in second column.

Area 20 PSC Gillnet Test Fishery

	Jul14-17		Jul18-24		Jul25-31	
N	111(111)		116(116)		58(58)	
WCVI	6.0%	3.1%	2.5%	2.9%	11.3%	6.6%
ECVI	19.8%	6.2%	21.3%	6.2%	18.6%	8.0%
NCVI	6.9%	3.9%	2.8%	3.6%	7.6%	5.2%
S. Mainland	8.1%	5.0%	13.0%	4.4%	10.1%	7.9%
Lower Fraser	25.1%	6.5%	17.8%	6.2%	19.1%	8.3%
Thompson	2.2%	1.7%	1.0%	2.1%	1.7%	1.5%
UPFR	0.0%	1.3%	0.0%	1.0%	0.0%	0.3%
Puget S.	22.7%	5.8%	32.3%	6.6%	29.7%	9.6%
Juan de Fuca	4.6%	2.9%	2.7%	3.0%	0.0%	2.9%
Coastal	4.8%	3.7%	4.8%	3.0%	0.0%	3.1%
Columbia	0.0%	1.4%	1.9%	1.6%	1.9%	3.2%
{Canada	68.0%	6.1%	58.3%	7.2%	68.3%	10.1%
{US	32.0%	6.1%	41.7%	7.2%	31.7%	10.1%

Area 20 PSC Seine Test Fishery

	Jul 21-24		Jul25-31		Aug1-Aug3		Aug8-14		Aug15-21		Aug22-28	
N	121(120)		172(171)		50(50)		99(98)		207(207)		63(63)	
WCVI	5.1%	2.8%	7.7%	2.2%	1.3%	3.3%	10.6%	4.4%	4.2%	2.4%	4.9%	4.8%
ECVI	15.0%	5.0%	11.2%	4.8%	12.4%	6.6%	21.8%	7.0%	17.8%	4.5%	22.7%	7.7%
NCVI	1.0%	1.8%	1.3%	1.8%	4.1%	4.0%	0.0%	3.3%	4.9%	2.3%	9.5%	5.0%
S. Mainland	10.0%	3.8%	11.4%	3.4%	18.2%	6.9%	11.0%	4.1%	10.1%	3.1%	15.1%	6.9%
Lower Fraser	27.6%	5.4%	24.6%	5.2%	6.3%	7.3%	18.3%	5.6%	19.5%	3.7%	11.0%	7.1%
Thompson	1.0%	1.1%	1.3%	1.1%	0.0%	0.3%	0.9%	1.7%	1.4%	1.1%	0.0%	1.0%
UPFR	0.0%	0.3%	0.0%	0.1%	0.0%	1.5%	0.0%	0.0%	1.5%	1.1%	0.0%	0.0%
Puget S.	32.2%	4.9%	30.1%	5.0%	51.2%	9.2%	26.7%	6.0%	29.4%	4.6%	33.6%	8.3%
Juan de Fuca	3.3%	2.1%	6.4%	2.5%	0.2%	4.4%	8.4%	4.4%	3.7%	2.3%	0.0%	2.3%
Coastal	4.8%	2.9%	3.2%	1.7%	6.3%	3.9%	0.7%	3.2%	3.5%	1.9%	0.0%	1.5%
Columbia	0.1%	1.3%	2.8%	1.3%	0.0%	1.7%	1.5%	2.1%	4.0%	1.7%	3.3%	3.1%
{Canada	59.6%	5.4%	57.4%	4.9%	42.3%	9.6%	62.6%	6.4%	59.4%	5.0%	63.1%	8.9%
{US	40.4%	5.4%	42.6%	4.9%	57.7%	9.6%	37.4%	6.4%	40.6%	5.0%	36.9%	8.9%

Appendix 2 Continued

Canadian Recreational Fisheries

	Area124/123 Aug16-Sept1		Area20(guides) Aug10-Oct1		Area20(BCWF) Aug15-Sep 5		Area20(food/sport) Aug 8-13		Area23Alberni/Ucluelet July7-Sep11		Area23Alberni/Bamfield July26-Aug1	
N	31(31)		18(18)		59(58)		204(203)		115(114)		247(247)	
WCVI	17.6%	8.1%	18.5%	9.3%	4.6%	3.9%	3.0%	2.1%	26.7%	5.3%	72.5%	3.9%
ECVI	10.4%	7.9%	19.4%	12.4%	21.1%	6.7%	17.7%	4.3%	19.0%	6.5%	5.7%	2.9%
NCVI	3.4%	4.3%	6.7%	7.7%	4.5%	3.3%	3.7%	2.7%	11.5%	4.4%	4.4%	2.1%
S. Mainland	7.5%	6.5%	12.6%	8.7%	8.7%	4.8%	10.5%	3.1%	10.2%	3.8%	6.4%	2.2%
Lower Fraser	33.8%	10.8%	22.1%	13.6%	17.8%	6.7%	20.7%	4.2%	18.8%	5.1%	4.2%	2.3%
Thompson	1.9%	3.0%	0.0%	0.2%	6.5%	3.5%	1.6%	1.1%	3.1%	2.1%	0.0%	0.5%
UPFR	0.0%	0.0%	0.0%	0.0%	3.8%	2.7%	0.0%	0.0%	0.0%	0.7%	0.4%	0.4%
Puget S.	10.4%	5.5%	9.6%	8.8%	27.4%	6.9%	29.6%	5.0%	3.8%	2.5%	5.3%	2.1%
Juan de Fuca	3.6%	4.2%	6.3%	9.6%	0.0%	0.9%	8.8%	2.6%	0.0%	1.1%	0.2%	0.6%
Coastal	8.1%	5.6%	0.5%	6.2%	5.6%	3.7%	1.4%	2.1%	6.9%	3.0%	0.6%	0.9%
Columbia	3.3%	1.6%	4.3%	5.8%	0.0%	1.2%	3.0%	1.8%	0.0%	1.1%	0.4%	0.6%
{Canada	74.6%	8.5%	79.3%	12.7%	67.1%	7.0%	57.2%	4.8%	89.3%	3.8%	93.5%	2.3%
{US	25.4%	8.5%	20.8%	12.7%	33.0%	7.0%	42.8%	4.8%	10.7%	3.8%	6.5%	2.3%

Washington State Fisheries

	Area5 treaty gillnet Aug4-5		Area4 treaty troll <Aug15		Area4/4b oc/str, Neah Bay 22-Aug		Area4 Ocean troll, Neah Bay 2-Sep		Area4 treaty troll Neah Bay Aug16-31		Area3 non-treaty troll Neah Bay Aug15-18	
N	44(44)		101(101)		207(207)		199(199)		180(180)		56(56)	
WCVI	6.9%	6.5%	0.0%	1.4%	6.0%	2.7%	2.9%	3.1%	6.8%	3.6%	0.3%	4.8%
ECVI	20.8%	8.8%	1.9%	4.2%	7.2%	3.8%	14.2%	4.7%	9.3%	4.8%	5.7%	6.3%
NCVI	4.4%	5.4%	5.2%	2.9%	4.1%	2.2%	4.7%	2.8%	1.9%	3.4%	9.8%	5.3%
S. Mainland	10.1%	7.3%	2.1%	3.0%	14.4%	3.6%	6.7%	3.1%	5.0%	2.6%	13.5%	5.4%
Lower Fraser	17.8%	6.8%	31.6%	6.7%	15.3%	4.4%	20.7%	4.6%	12.3%	4.1%	10.5%	5.0%
Thompson	1.7%	3.3%	5.9%	2.3%	1.6%	1.3%	2.2%	1.3%	3.9%	1.8%	3.2%	2.2%
UPFR	0.0%	0.0%	0.0%	1.0%	0.0%	0.3%	0.0%	0.7%	0.0%	0.6%	0.0%	0.8%
Puget S.	31.2%	8.0%	43.6%	6.5%	23.3%	4.4%	26.2%	5.0%	23.6%	5.2%	15.6%	8.4%
Juan de Fuca	4.1%	3.3%	0.1%	3.0%	3.0%	1.9%	4.2%	2.4%	7.5%	3.7%	0.0%	2.7%
Coastal	0.0%	2.6%	6.7%	3.4%	14.6%	3.7%	14.0%	3.8%	16.6%	5.1%	28.7%	7.9%
Columbia	3.0%	3.0%	2.8%	2.4%	10.6%	2.9%	4.2%	2.3%	13.1%	3.2%	12.7%	5.6%
{Canada	61.7%	9.0%	46.8%	6.6%	48.6%	4.6%	51.4%	5.5%	39.2%	7.6%	43.0%	9.3%
{US	38.3%	9.0%	53.2%	6.6%	51.4%	4.6%	48.6%	5.5%	60.8%	7.6%	57.0%	9.3%

Appendix 2 Continued

Troll Fisheries

	Area 12		Area11		Area123		Area123		Area123	
	Jul23-Aug6		3-Aug		Jul25-31		Aug12-13		Sep2-14	
N	158(157)		23(23)		194(193)		204(203)		211(210)	
WCVI	17.3%	4.8%	16.0%	11.4%	4.4%	2.6%	3.8%	2.5%	7.8%	2.5%
ECVI	16.1%	4.9%	5.8%	8.6%	14.4%	4.4%	14.3%	4.0%	16.6%	4.2%
NCVI	14.7%	4.7%	27.6%	11.7%	4.2%	2.4%	3.4%	2.5%	0.9%	2.1%
S. Mainland	31.7%	5.5%	20.8%	9.8%	7.6%	3.0%	5.0%	2.7%	5.5%	3.0%
Lower Fraser	10.4%	3.2%	14.6%	9.9%	25.3%	4.7%	26.0%	4.0%	36.5%	4.9%
Thompson	0.0%	0.7%	8.4%	5.8%	3.5%	1.6%	2.2%	1.2%	1.0%	0.9%
UPFR	0.0%	0.2%	0.0%	0.0%	0.0%	0.5%	0.5%	0.8%	0.5%	0.4%
Puget S.	5.2%	2.7%	0.0%	6.1%	21.7%	3.9%	28.1%	4.1%	21.8%	4.2%
Juan de Fuca	2.0%	1.4%	0.6%	3.5%	11.3%	2.9%	6.4%	2.1%	0.0%	1.6%
Coastal	0.3%	1.6%	6.1%	2.6%	6.7%	2.4%	6.2%	2.6%	5.8%	2.1%
Columbia	2.4%	1.6%	0.0%	3.5%	1.0%	1.0%	4.2%	1.8%	3.6%	1.7%
{Canada	90.2%	3.4%	93.3%	7.2%	59.3%	5.2%	55.1%	5.4%	68.8%	4.4%
{US	9.8%	3.4%	6.7%	7.2%	40.7%	5.2%	44.9%	5.4%	31.2%	4.4%

Troll Fisheries

	Area124		Area124		Area124		Area124		Area125		Area125	
	Jul23-Jul31		Aug1-Aug7		Aug8-Aug14		Sep12-15		Jul25-Jul31		Aug1-Aug13	
N	260(258)		110(110)		199(199)		191(190)		264(262)		142(142)	
QCI	0.6%	1.0%	0.0%	0.6%	2.6%	1.3%	2.3%	1.5%	0.7%	0.6%	0.4%	0.9%
Nass	0.0%	0.8%	1.0%	1.2%	1.0%	1.6%	0.8%	1.3%	1.9%	1.2%	0.0%	1.1%
Upper Skeena	1.6%	1.0%	0.0%	0.5%	1.1%	1.3%	0.1%	0.7%	0.6%	0.7%	1.9%	1.4%
Lower Skeena	3.8%	2.3%	0.8%	2.1%	7.5%	2.9%	0.5%	1.2%	2.8%	1.7%	1.9%	2.3%
North/Central Coast	8.0%	2.9%	6.7%	3.5%	7.6%	2.9%	3.7%	2.8%	3.6%	2.3%	2.8%	2.3%
WCVI	22.1%	3.3%	19.7%	5.7%	16.2%	4.3%	29.7%	4.6%	13.5%	3.1%	14.8%	4.0%
ECVI	12.2%	3.7%	12.1%	5.1%	19.8%	3.7%	14.2%	4.6%	13.4%	3.7%	17.4%	5.0%
NCVI	9.0%	3.1%	2.4%	3.5%	6.9%	2.6%	13.3%	4.2%	10.0%	2.8%	5.8%	2.7%
South Main	3.7%	2.3%	3.0%	2.5%	1.6%	1.8%	4.5%	2.4%	8.4%	2.9%	1.9%	2.2%
Lower Fraser	22.7%	3.9%	22.7%	4.4%	20.3%	3.8%	18.2%	3.6%	25.1%	3.7%	31.3%	5.7%
Thompson	1.1%	1.0%	1.1%	1.6%	0.0%	0.6%	0.5%	0.7%	1.1%	0.9%	3.3%	2.1%
UPFR	1.1%	0.7%	1.1%	1.0%	0.5%	0.7%	0.0%	0.1%	2.2%	1.3%	3.0%	1.5%
Puget Sound	8.2%	2.4%	19.2%	4.4%	8.2%	2.5%	6.6%	2.7%	11.7%	2.5%	5.3%	2.6%
Juan de Fuca	3.2%	1.6%	0.0%	1.8%	3.3%	1.6%	1.6%	1.3%	0.3%	1.0%	3.7%	2.3%
Coastal Wash	2.2%	1.5%	9.0%	2.7%	3.4%	1.8%	3.3%	1.7%	3.6%	1.6%	3.2%	2.3%
Columbia	0.5%	0.6%	1.0%	1.6%	0.0%	0.3%	0.8%	1.1%	1.3%	0.7%	3.4%	1.8%
{Canada	85.9%	3.2%	70.8%	5.1%	85.1%	3.3%	87.8%	2.9%	83.1%	2.6%	84.5%	4.1%
{U.S.	14.1%	3.2%	29.2%	5.1%	14.9%	3.3%	12.2%	2.9%	16.9%	2.6%	15.5%	4.1%

Troll Fisheries con't

	Area126		Area127		Area123-125/124-125/124-126/125-126/125-127	
	Jul26-Aug13		Jul23-Aug4		Jul23-Aug2	
N	219(219)		126(126)		195(195)	
QCI	0.9%	0.9%	4.0%	2.1%	0.4%	0.9%
Nass	3.4%	2.3%	0.0%	1.2%	0.0%	1.3%
Upper Skeena	0.6%	1.0%	1.4%	1.9%	1.9%	1.1%
Lower Skeena	3.5%	1.9%	2.7%	2.8%	4.8%	2.3%
North/Central Coast	4.4%	2.6%	12.3%	4.7%	6.3%	2.6%
WCVI	15.9%	3.9%	21.6%	5.4%	15.7%	3.2%
ECVI	17.2%	4.1%	8.5%	3.6%	9.2%	3.5%
NCVI	5.5%	2.4%	17.3%	3.9%	8.6%	3.3%
South Main	5.9%	2.5%	6.4%	3.7%	5.2%	2.5%
Lower Fraser	28.5%	4.5%	11.8%	3.8%	26.4%	3.9%
Thompson	1.3%	1.3%	0.0%	1.0%	0.1%	0.8%
UPFR	0.0%	0.6%	0.7%	1.0%	0.8%	0.7%
Puget Sound	4.0%	1.9%	4.7%	2.9%	13.5%	3.7%
Juan de Fuca	3.1%	1.5%	4.3%	2.3%	3.8%	1.9%
Coastal Wash	4.7%	1.9%	4.4%	2.0%	1.6%	1.6%
Columbia	1.1%	0.9%	0.0%	0.3%	1.7%	1.3%
{Canada	87.0%	3.2%	86.6%	3.9%	79.4%	3.9%
{U.S.	13.0%	3.2%	13.4%	3.9%	20.6%	3.9%

Appendix 2 Continued

Recreational Fisheries - North coast	Area3 26-Jul		Area4 Jul 25-Aug 15		Langara Isl. 23-Aug		Area8/9 Siezed Fish Aug13/Oct 24	
N	135(133)		30(30)		71(69)		40(40)	
S.E. Alaska	2.8%	2.1%	2.3%	3.7%	0.0%	2.0%	0.0%	2.4%
QCI	3.4%	2.3%	2.1%	2.5%	19.8%	4.8%	3.5%	4.0%
Nass	5.0%	3.0%	0.0%	3.2%	8.6%	4.0%	2.9%	3.3%
Upper Skeena	13.8%	3.8%	7.4%	5.3%	0.1%	2.4%	0.0%	1.8%
Lower Skeena	23.8%	5.7%	16.2%	8.9%	11.0%	5.6%	0.0%	4.8%
North/Central Coast	22.9%	4.7%	26.9%	10.1%	16.8%	6.8%	26.4%	8.9%
Vancouver Isl.	18.8%	5.1%	24.2%	10.9%	21.4%	6.4%	29.0%	9.0%
South Main	5.3%	3.0%	7.4%	5.4%	2.7%	3.6%	9.7%	6.4%
Lower Fraser	2.7%	2.1%	3.6%	4.6%	6.2%	4.5%	11.5%	8.0%
Thompson	0.0%	0.5%	0.0%	2.0%	0.0%	0.2%	0.0%	0.9%
UPFR	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%
Puget Sound	0.0%	1.3%	4.3%	5.4%	2.6%	2.6%	13.6%	6.2%
Juan de Fuca	0.0%	0.4%	0.0%	2.2%	0.1%	1.7%	0.0%	0.7%
Coastal Wash	0.7%	0.9%	3.8%	4.0%	10.7%	4.9%	3.4%	3.4%
Columbia	0.8%	0.4%	1.8%	2.8%	0.0%	0.4%	0.0%	0.6%
{Canada	95.7%	2.6%	87.8%	7.5%	86.7%	5.5%	83.0%	6.9%
{U.S.	4.3%	2.6%	12.2%	7.5%	13.3%	5.5%	17.0%	6.9%

LWFR River Fisheries (Area29)	Comm. Gillnet Oct10-Nov6		A29Sel#371 Oct16-Oct31		A29SelKadi Oct16-Oct30		Sooktrap Sep27-Oct22		DarcieHook Sep29-Oct24	
N	82(81)		34(34)		23(23)		28(28)		160(160)	
Lower Fraser	97.1%	3.0%	100.0%	3.1%	95.6%	4.7%	92.5%	5.6%	96.8%	1.9%
Thompson	2.9%	2.7%	0.0%	2.7%	4.4%	4.5%	0.2%	1.6%	3.2%	1.8%
UPFR	0.0%	0.8%	0.0%	1.5%	0.0%	1.0%	7.3%	5.5%	0.0%	0.7%

LWFR river Test Fisheries Tangle net	Prior to Sept. 22		Sept 23 - Oct 02		Oct 03 - 08		Oct 09 - 15		Oct 16 -22		Oct 23-Nov 15	
	179(179)		66(66)		56(56)		82(82)		163(163)		76(76)	
Lower Fraser	58.6%	4.9%	81.5%	5.9%	93.8%	5.9%	93.5%	3.3%	97.3%	2.8%	96.8%	2.7%
Thompson	33.8%	4.5%	10.3%	5.6%	5.7%	5.2%	3.0%	2.5%	2.3%	2.4%	1.2%	2.2%
UPFR	7.6%	3.0%	8.2%	5.2%	0.6%	3.5%	3.5%	2.6%	0.4%	1.4%	2.0%	1.9%

Yale Fishwheel

	1998			
	Sep21-30		Oct1-Nov19	
	123(134)		137(137)	
Thompson	77.5%	5.5%	82.2%	4.7%
UPFR	22.5%	5.5%	17.9%	4.7%

	1999	
	Sep9-Oct3	
	97(97)	
Thompson	84.6%	5.2%
UPFR	15.4%	5.2%

Appendix 3. Estimates of Survivals to Adult (3 yrs old) and Marine Fishery Expoitation Rates for Enhanced Coho Released into Ea R. and Salmon R. (S. Thompson), Louis and Lemieux Creeks (N. Thompson), and Spius Ck (S. Thompson).

Return Year	Stream	Life Stage Released	Number CWT'ed	Estimated Can. Catch	Estimated Wa/Ore Catch	Estimated Total Catch	Estimated Escape.	Percent Survival	Can. Mar. Exploit.	Total Mar. Exploit.
1987	Eagle	Spring Fry	128,519	755	127	882	863	1.36	0.43	0.51
	Eagle	Fall Fry	81,174	723	174	897	727	2.00	0.45	0.55
	Eagle	Smolts	26,983	360	80	440	521	3.56	0.37	0.46
	Salmon	Spring Fry	102,835	672	119	791	482	1.24	0.53	0.62
	"Unweighted Mean"							2.04	0.45	0.53
	"Unweighted Mean" - smolts only							3.56		
	Wted-all fish	Total	339,511	2,510	500	3,010	2,593	1.65	0.45	0.54
1988	Eagle	Spring Fry	146,315	1,298	341	1,639	489	1.45	0.61	0.77
	Eagle	Fall Fry	45,392	623	157	780	267	2.31	0.60	0.74
	Eagle	Smolts	29,685	817	186	1,003	354	4.57	0.60	0.74
	Salmon	Spring Fry	104,433	1,114	200	1,314	806	2.03	0.53	0.62
	"Unweighted Mean"							2.59	0.58	0.72
	"Unweighted Mean" - smolts only							4.57		
	Wted-all fish	Total	325,825	3,852	884	4,736	1,916	2.04	0.58	0.71
1989	Eagle	Spring Fry	141,046	699	182	881	309	0.84	0.59	0.74
	Eagle	Fall Fry	45,772	506	99	605	356	2.10	0.53	0.63
	Eagle	Smolts	30,704	1,180	246	1,426	899	7.57	0.51	0.61
	Salmon	Spring Fry	103,770	665	265	930	549	1.43	0.45	0.63
	"Unweighted Mean"							2.99	0.52	0.65
	"Unweighted Mean" - smolts only							7.57		
	Wted-all fish	Total	321,292	3,050	792	3,842	2,113	1.85	0.51	0.65
1990	Eagle	Spring Fry	94,328	420	160	580	91	0.71	0.63	0.86
	Eagle	Fall Fry	49,041	420	40	460	226	1.40	0.61	0.67
	Eagle	Smolts	65,027	1,167	168	1,335	498	2.82	0.64	0.73
	Salmon	Spring Fry	106,743	348	70	418	184	0.56	0.58	0.69
	"Unweighted Mean"							1.37	0.61	0.74
	"Unweighted Mean" - smolts only							2.82		
	Wted-all fish	Total	315,139	2,355	438	2,793	999	1.20	0.62	0.74
1991	Eagle	Spring Fry	101,162	127	72	199	86	0.28	0.45	0.70
	Eagle	Fall Fry	51,006	54	27	81	51	0.26	0.41	0.61
	Eagle	Smolts	64,528	99	43	142	98	0.37	0.41	0.59
	Salmon	Spring Fry	112,509	129	35	164	44	0.18	0.62	0.79
	"Unweighted Mean"							0.27	0.47	0.67
	"Unweighted Mean" - smolts only							0.37		
	Wted-all fish	Total	329,205	409	177	586	279	0.26	0.47	0.68
1992	Eagle	Spring Fry	81,200	441	41	482	94	0.71	0.77	0.84
	Eagle	Fall Fry	48,460	319	22	341	64	0.84	0.79	0.84
	Eagle	Smolts	56,482	825	51	876	168	1.85	0.79	0.84
	Salmon	Spring Fry	109,322	573	53	626	203	0.76	0.69	0.76
	"Unweighted Mean"							1.04	0.76	0.82
	"Unweighted Mean" - smolts only							1.85		
	Wted-all fish	Total	295,464	2,158	167	2,325	529	0.97	0.76	0.81
1993	Eagle	Spring Fry	53,118	109	28	137	15	0.29	0.72	0.90
	Eagle	Fall Fry	56,336	152	38	190	15	0.36	0.74	0.93
	Eagle	Smolts	57,872	128	18	146	15	0.28	0.80	0.91
	Salmon	Spring Fry	56,373	150	17	167	46	0.38	0.70	0.78
	"Unweighted Mean"							0.33	0.74	0.88
	"Unweighted Mean" - smolts only							0.28		
	Wted-all fish	Total	223,699	539	101	640	91	0.33	0.74	0.88

Appendix 3 continued. Estimates of Survivals to Adult (3 yrs old) and Marine Fishery Expoitation Rates

Return Year	Stream	Life Stage Released	Number CWT'ed	Estimated Can. Catch	Estimated Wa/Ore Catch	Estimated Total Catch	Estimated Escape.	Percent Survival	Can. Mar. Exploit.	Total Mar. Exploit.
1994	Eagle	Fall Fry	52,817	29	2	31	40	0.13	0.41	0.44
	Salmon	Smolts	9,700	47	0	47	62	1.12	0.43	0.43
	"Unweighted Mean"							0.63	0.42	0.43
	"Unweighted Mean" - smolts only							1.12		
	Wted-all fish	Total	62,517	76	2	78	102	0.29	0.42	0.43
1995	Eagle	Spring Fry	96,353	212	52	264	44	0.32	0.69	0.86
	Eagle	Smolts	35,963	210	16	226	44	0.75	0.78	0.84
	Salmon	Spring Fry	49,910	97	7	104	136	0.48	0.40	0.43
	Salmon	Smolts	20,360	113	13	126	144	1.33	0.42	0.47
	Lemieux	fry	19,831	110	15	125	213	1.70	0.33	0.37
	Lemieux	smolt	7,636	64	23	87	156	3.18	0.26	0.36
	Louis	smolt	9,093	142	20	162	117	3.07	0.51	0.58
	"Unweighted Mean"							1.55	0.48	0.56
	"Unweighted Mean" - smolts only							2.08		
	"Unweighted Mean" - South Thompson smolts only							1.04		
	"Unweighted Mean" - North Thompson smolts only							3.13		
	Wted-all fish	Total	239,146	948	146	1,094	854	0.81	0.49	0.56
1996a	Eagle	Fall Fry	35,116	107	16	123	13	0.39	0.79	0.90
	Salmon	Fall Fry	35,654	26	4	30	29	0.17	0.44	0.51
	Lemieux	smolt	17,170	347	32	379	38	2.43	0.83	0.91
	Louis	smolt	13,050	456	39	495	123	4.74	0.74	0.80
	"Unweighted Mean"							1.93	0.70	0.78
	"Unweighted Mean" - smolts only							3.58		
	Wted-all fish	Total	100,990	936	91	1,027	203	1.22	0.76	0.83
1997b	Lemieux	smolt	10,000	13	8	21	60	0.81	0.16	0.26
	Louis	smolt	10,000	44	35	79	87	1.66	0.27	0.48
	"Unweighted Mean"							1.24	0.21	0.37
	"Unweighted Mean" - smolts only							1.24		
	Wted-all fish	Total	20,000	57	43	100	147	1.24	0.23	0.40
1998 c,d	Lemieux	smolt	9,900	1	2	3	33	0.36	0.03	0.08
	Spius	smolt	40,020			32	428	1.15	0.02	0.07
	"Unweighted Mean"							0.76	0.02	0.08
	"Unweighted Mean" - smolts only							0.76		
	Wted-all fish	Total	49,920			35	461	0.99		0.07
1999 e	Spius	smolt	40,000			57	639	1.74	0.03	0.09
	Lemieux	smolt	6,936			18	194	3.06	0.03	0.09
	"Unweighted Mean"							2.40	0.03	0.09
	"Unweighted Mean" - smolts only							2.40		
	Wted-all fish	Total	46,936			75	833	1.93		0.09

a. Louis escapement includes 2 cwt strays recovered in Lemieux that were from Louis
b. Lemieux escapement includes 28 cwt strays recovered in Louis that were from Lemiuex and
Louis escapement includes 1 cwt stray recovered in Lemieux that was from Louis
c. There was no recorded Can. catch in 1998. However, DNA evidence suggests a 2% exploitation rate in Canada
due to catch and release mortality so 1 Can caught fish added to total.
d. For Spius in 1998, assumed to be 2% exploitation in Canada and 5% in USA
e. For Spius and Lemieux in 1999, assumed to be 3% in Canada and 6% in USA